University of Southern Queensland
Faculty of Engineering and Surveying

Improving the Performance of the Nanango Wastewater Treatment Plant

A dissertation submitted by

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Abstract

The principle aim of the research was to find methods of improving the efficiency and performance of the Nanango wastewater treatment plant with a particular focus on the secondary treatment process and replacing the aerators.

The research into the Nanango wastewater treatment plant has shown that it has been in operation in its current configuration since 1984 with no upgrades to the system or treatment process. In recent years the aeration process had been shown a decline in performance with the aerators themselves breaking down on a regular bases.

Research into wastewater treatment processes and theories, was used to compare the process in operation at the NWWTP. The data and information supplied from the NTP was used to identify possible methods of improving the current treatment process efficiency and quality of effluent.

The research will show that the NWWTP problems or operational issues that it have been experiences with the secondary treatment process and aerators may not be due to the age of the aeration equipment. A lack of process control, system monitoring and testing would make it wrong to assume that these processes and operation were the contributing factors to the problems experienced at the NTP.

The recommendations of this project will hopefully help the South Burnett Regional Council make the choice to study the NWWTP process in order to gain a better understand of what is happening within the system before spending capital on new equipment.

University of Southern Queensland
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ENG4111 Research Project Part 1 &
ENG4112 Research Project Part 2

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Terminology and Abbreviations

BOD - Biological Oxygen Demand

COD - Chemical Oxygen Demand

DO - Dissolved Oxygen

HP - Horse Power

kW - Kilo Watts

NTP - Nanango Treatment Plant

NWWTP - Nanango Wastewater Treatment Plant

MLSS - Mixed Liquor Suspended Solids

MLVSS - Mixed Liquor Volatile Suspended Solids

mg/L - Milligrams per Litre

OD - Oxidation Ditch

RPM - Revolutions per Minute

SS - Suspended Solids

TSS - Total Suspended solids

VOC - Volatile Organic Chemical

WWTP - Wastewater Treatment Plant

Chapter 1 Introduction

1.1 Outline

The research in this project was conducted to enhance the treatment of wastewater at the Nanango wastewater treatment plant through increasing the efficiency of the plant while reducing the power consumption. The Nanango wastewater treatment is a secondary or biological treatment plant, which is owned and operated by the South Burnett Regional Council (SBRC). As part of the National Governments, Energy Efficiency Opportunities program, the SBRC carried out audits and reviews of its assets over the whole South Burnett region. Through the audit and review process the SBRC flagged its wastewater treatment plants in Kingaroy, Nanango, Wondai and Murgon as areas where it can reduce its overall power consumption.

The project will investigated the current treatment process, with focus on the design of the oxidation ditch (OD), the aerators and aeration process, the activated sludge process, the systems process control and the monitoring of the systems employed at the NWWTP. Research was conducted into the background, theory, and history of wastewater treatment was conducted to consider alternative methods of treatment through improved aeration techniques or chemical enhancement in an attempt to improve the efficiency of the current treatment process. Research was also conduct into a control and monitoring systems that could be integrated into the treatment process to help improve and control the system and processes. The data and information gathered will be compare NWWTP process and equipment to allow for an assessment of the treatment process and how it compares to other wastewater treatment plants and processes.

The data and equipment from the current Nanango wastewater treatment process was used as a base line to investigate replacement/enhancements and alternative aerators. The data and information collected well also be used to evaluate the possibility of adding chemicals as an alternative wastewater treatment process which will improve the process efficiency and power efficiency of the treatment plant.

1.2 Background

The community of Nanango was settled in 1847, with the first wastewater treatment plant was built in 1950s. The current wastewater treatment plant in operation which is used to service the community of Nanango was constructed in 1984 as a plant upgrade from the original plant. This upgrades were carried out as part of the expected increase in population between 1976 and 1986 due to the construction of the Tarong power station and coal mine. The plant in its current configuration is designed to handle the wastewater influent for a population inflow volume from 3500 persons. The location of the treatment plant has enough available surrounding land to increase the plants treatment capacity as it may be required in the future.

The treatment process is a simple secondary wastewater treatment process that uses five steps to achieve the required wastewater treatment level. The process involves a primary mechanical screening, an oxidation ditch for the aeration process, a secondary clarifier for the activated sludge process, a chlorination tank for the disinfection process and a dewatering lagoon. The process used at the Nanango treatment plant was designed to operate and comply with the state/national compliance laws for the discharge of treated wastewater in 1984. It is not known if the site meets the standard of discharged required by the discharge licence issued to the plant, because it wasn't supplied for this project.

1.3 Aim

This project aims to provide sufficient literature and research on wastewater treatment in order to compare the current wastewater treatment and plant processes in operation at the NTP. The project will also give a board understanding of what is wastewater, the types of wastewater, the equipment used in the treating of wastewater, and the alternative methods and processes of treating wastewater. The research will be used to make recommendations on methods to improving the efficiency of the current process employed at the NTP. The project will investigate the plants processes and process control, which are used in the operation of the NTP and how the processes are monitored, and tested with a focus on reducing the power used and understanding the system. The report will provide detailed research into the aerations process compared to the Nanango aeration process with a focus on oxidation ditch, the aerators, and the activated sludge. It will also look at the possibility of adding chemicals to reduce energy cost and accelerate the treatment process. The research and recommendations into more efficient methods of processing the wastewater at Nanango will be used to provide the SBRC with an outline on where the plant can be upgrade to reduce power consumption.

1.4 Objectives

The objectives of this research it to present information and data for improving the efficiency of the Nanango wastewater treatment plant. Research will also be carried out on alternative treatment methods that will increase the efficiency of the Nanango wastewater treatment plant and processes. Through the improvements in the treatment process. The project also will focus on methods of reducing the sites power consumption. The project will aim to help the SBRC highlight current operational process deficiencies which can be improved to bring the plant up to a modern operating environment and meet the State Governments energy consumption requirements.

The research is required to provide data and information on the current and alternative methods of aerating influent wastewater in an oxidation ditch to increase the efficiency of the aeration process through improving the current control process. A chemical alternative will be researched as a possible method on increasing the treatment plants overall efficiency to the carrier media. The current process will be compared to the alternatives and the data collected will estimate the reduction in power usage from the available alternative aeration treatment. From the research recommendations will be made for the most feasible alternative and the best approach that will increase the efficiency of the treatment process while reducing the power consumption of the plant.

Chapter 2 Wastewater and Treatment

2.1 Introduction

The studies already undertaken into wastewater treatment is very extensive and well documented. This chapter will give a broad explanation of what constitutes wastewater. The chapter will investigate the type of wastewater, where it comes from and what can be found in wastewater. It will also explain the effect wastewater can have on the have on public health and the environment if left untreated or not treated correctly. The chapter will then turn the focus to the design of wastewater treatment plants. The final section of the chapter will deal with different types of equipment and configurations that can be employed at a treatment plant. The chapter will also including the physical and chemical treatment processes available and discuss the role and importance each process plays in the treatment of wastewater.

2.2 Background

Every community produces both liquid and solid waste and the correct treatment and deposal of the waste is essential to the health of the community and the environment. The liquid waste or wastewater is essentially the water supply of the community after it has been used in application such as toilets, kitchens, bathrooms and laundries. The wastewater can also include water from a variety of other sources such as street and land runoff, the water washed down drains at commercial and industrial facilities. The type of wastewater received at a wastewater treatment facility will vary depending on the design of the sewer network.

2.3 Wastewater

Wastewater is characterised in terms of it physical, chemical, and biological composition (Metcalf and Eddy, 2003). From the stand point of sources of generation, wastewater may be defined as a combination of the liquid or water carried wastes removed from residences, institution, and commercial and industrial establishments, together with such groundwater, surface water, and stormwater as my be present (Metcalf and Eddy, 2003). The wastewater that arrives at the treatment plants to be processed contains much more than just water and solid waste. It can contain thousands of different chemicals, organic and inorganic materials that can or cannot be broken down in the natural environment or in the treatment process without causing harm. The chemical, organic and inorganic materials that can't be treated need to be removed before the wastewater can be safely discharged into a receiving body of water, or land or treated further for reuse. The wastewater that is treated at a WWTP can go through a number of different processes depending on the size of the plant and the type of wastewater it is treating. The treatment process can involve many processes in many combinations from screening, grit removal, solid separation and settling, chemical treatment and disinfection. The wastewater need to go through the correct treatment process so it cannot cause damage to WWTP, the environment or public health.

2.4 Public Health and the Environment

Even with the extensive and advance wastewater treatment processes available today protecting the public health and the environment still remains a high priority for the wastewater industry. If the treatment process is inadequately designed to handle the type and volume of wastewater, or the plant is damaged the discharge effluent can cause severe and irreparable damage to the receiving wasters and land environment (Department of Sustainability et al., 1997). The discharge can have a number of different effects on public health and the environment, from aesthetics, pathogens, nutrients, toxicants, and dissolved solids. Temperature and BOD increases are also a issue to public health and the environment, but are a direct result of the discharges listed above and are generally included in their review.

- The aesthetic damage from wastewater is the most noticeable, because of changes in water or land colour and odour, from solids such as, plastics, foam, oil, greases and suspended solids effluent are all easily seen and smelt.

- Faecal wastes from human and other animals contain micro-organisms capable of producing illness. Pathogens include viruses, bacteria, fungi, and protozoan and metazoan parasites (Department of Sustainability et al., 1997). Unlike the aesthetic damage pathogens cannot be seen and they are nearly impossible to monitor because of the number of different species. Pathogens if not treated correctly can have enormous effects on the health of the public and environment.

- Nutrients, such as nitrogen and phosphorus are found in wastewater a high concentration. Both nutrients are found in the natural ecosystem, but increased levels in the naturally occurring levels can cause organisms detrimental to the waterway to thrive at the expense of others. consumed or irritation, rashes and asthma when it comes in contact with the skin or inhaled.

- Toxicants, such as toxic heavy metals and toxic organic compounds, enter wastewater treatment through the released of pesticides and herbicides from agricultural runoff, urban runoff from roads and discharge of industrial waste. If toxicants are discharged untreated in large quantities, they can render the discharge body, water or land unusable for long periods. Once these toxins contaminates reach surface waters, they may concentrate through aquatic food chains and bio-accumulate in fish and shellfish tissue (United States Environmental Protection Agency, 2000a).

- Dissolved solids are the particles that are small enough to passes through the filters and are generally removed from the waste water via evaporation. The dissolved solids such as salts, trace contaminants and ions such as chloride and sodium that pass through the filters can cause changes to the discharge body. Of particular concern are the dissolved solids can cause a rises in salinity levels of the discharge body.

2.5 Wastewater Plant Design

The design of a wastewater treatment plant and the processes, will differ from one treatment plant to the next, depending on several factors such as; Population and flow projections for areas served by a wastewater treatment plant should be made before sizing of treatment processes and pipping (Water Environment Federation, 2003). The population and flow projection also need to account for non-permanent residents and changes in population due to tourism or entertainment and commercial events. The design of the treatment plant and piping must be able to handle large fluctuations in the flow from infiltration and inflow, depending on the pipe network. Pipe networks can consist of straight raw sewerage network or a combined network consisting on raw sewerage and stormwater.

Some of the most significant components of wastewater received at a treatment plant include infiltration, which refers to water seepage through collection systems pipes and vaults, and inflows, which refers to surface and subsurface stormwater entering the collection system (Water Environment Federation, 2003).

2.6 Wastewater Treatment Process

The alternatives for municipal wastewater treatment fall into three major categories: (1) primary treatment, (2) secondary treatment, and (3) advance treatment (Mackenzie L. Davis and David A. Cornwell, 2008).

2.6.1 Primary Treatment

The primary wastewater treatment process for this project will include the pre-treatment or preliminary treatment processes as part of the primary treatment process as discussed in Davis and Cornwell (2008) and not as a separate category as discussed in Spellman (2009). The Primary treatment process uses several devices and structures to remove pollutants and organic material that can create problems to the treatment processes further downstream. These devices and structures are classified as pre-treatment because they have little effect in reducing BOD (Mackenzie L. Davis and David A. Cornwell, 2008). Eliminating or controlling the problems like large solids, rags, abrasive grit, odours and variation caused by inflow and infiltration, will allow the next phases in the treatment process to function more efficiently. Also by reducing harmful the amount of material before entering pumps and pipes will have an effect on maintenance down time and repairs costs. Primary treatment, will typically remove about 60 percent of the suspended solids in the raw sewage and 35 percent of the BOD (Mackenzie L. Davis and David A. Cornwell, 2008). The primary treatment process which includes per-treatment consists of a four major categories, (1) screening, (2) grit removal, (3) equalization, and (4) primary settling.

Industrial Wastewater

Industrial source wastewater may be required to pass through an onsite per-treatment process before it can be released into a sewer network. Industrial waste can contain hazardous material, If allowed to discharged directly into the municipal wastewater system, can cause damage to the sewers, treatment plants or pass through the wastewater treatment plant untreated and be discharged directly into the environment. To minimize the effect of industrial wastewater the Australian Government introduced the *Acceptance of Trade Waste (Industrial Waste*) as part of its National Water Quality Management Strategy (from the publication: Guidelines for Sewerage Systems). The document outlines the guidelines on trade wastewater (industrial wastewater) through management program, legislation, compliance monitoring and inspection, and responsibilities of trade waste generators. These guidelines have been released by the Natural Resource Management Ministerial Council (NRMMC) and, in some cases, in collaboration with the National Health and Medical Research Council (NHMRC) and the Australian Health Ministers Conference (Department of Sustainability et al., 1994).

Screening

Screening is the first step the wastewater treatment, its process purpose is to removes large solids and pollutants from wastewater thus protecting the operation and equipment further downstream. There are different types of screens available, course screen with openings of 6mm and larger, fine screens with openings of 1.5mm to 6mm and very fine screens with openings of 0.2mm to 1.5mm. There is also a range of operating methods for the screens, with units that are require manual cleaning by an operator, to several systems that are mechanically operated and self cleaning. More than one screen can be used in the screening process, depending on the amount of solids and pollutants that need to be removed, the type of wastewater inflow, budget, and running costs.

Grit Removal

Grit removal, is the process of removing dense material, such as sand, gravel, broken glass, silt, pebbles and organics undergoing the process of decay such as coffee, egg shells, fruit rinds and seeds from the wastewater. The grit if not removed can cause unnecessary abrasion and wear to pipes, pumps and seals, it can also cause blockages from build up of grit in corners and bends. There are three basic types of grit-removal devices: velocity controlled (horizontal-flow), aerated, and constant-level short-term sedimentation basins (Mackenzie L. Davis and David A. Cornwell, 2008).

Equalization

Equalization or flow equalization is not a method for treating wastewater, but a technique used to improve the flow rate of the wastewater in the system.

Primary Settling

Primary settling tanks are used to remove some of the remaining organic suspended solids that are light enough to pass through the screening and grit removal process. The primary settling process and tanks are also referred to as sedimentation tanks and classifiers. These suspended solids contribute to biochemical oxygen demand (BOD 5) of the wastewater (Davis, 2010). The gravitational separation causes the heavier particles to fall to the bottom of the tank and form a settled mass call raw sludge. Substances such as grease, oil, and foam and light particles are removed from the surface of the tank by skimmer for further processing. Any remaining organic materials that neither float to the surface nor sink into the sludge are carried out of the tank with the flow of the wastewater to the next process. Table 1 summaries the other phenomena's that can be used to improve the gravitational separation process.

Type of Separation Phenomenon	**Description**	**Application/occurrence**
Discrete Particle settling	Refers to the settling of particles in a suspension of low solid concentration by gravity in a constant acceleration field. Particles settle as individual entities, and there is no significant interaction with neighbouring particles	Removal of grit and sand particles from wastewater
Flocculent Settling	Refers to a rather dilute suspension of particles that coalesce, or flocculate the settling operation. By coalescing, the particles increase in mass and settle at a faster rate	Removal of a portion of the TSS in untreated wastewater in primary settling facilities, and in upper portions of secondary setting facilities. Also removes chemical floc in settling tanks
Ballasted flocculent settling	Refers to the addition of an inert ballasting agent and a polymer to a partially flocculate suspension to promote rapid settling and improve solids reduction. A portion of the recovered ballasting agent is recycled to the process	Removal of a portion of the TSS in untreated wastewater, wastewater from combined systems, and industrial wastewater. Also reduces BOD and phosphorus
Hindered settling (also called zone settling)	Refers to suspensions of intermediate concentration, in which inter-particles forces are sufficient to hinder the settling of neighbouring particles. The particles tend to remain in fixed positions with respect to each other, and the mass of particles settles as a unit. A solid-liquid interface develops at the top of the settling mass	Occurs in secondary settling facilities used in conjunction with biological treatment facilities
Compression settling	Refers to settling in which the particles are of such concentration that a structure is formed, and further settling can occur only by compression of the structure. Compression takes place from the weight of the particles , which are constantly being added to the structure by sedimentation from the supernatant liquid	Usually occurs in the lower layers of a deep solids or bio-solids mass, such as in the bottom of deep secondary settling facilities and in solids-thickening facilities.
Accelerated gravity settling	Removal of particles in suspension by gravity settling in an accelerated field	Removal of grit and sand particles from wastewater
Flotation	Removal of particles in suspension that are lighter than water by air or gas flotation	Removal of greases and oils, light material that floats, thickening of solids suspensions

Table 1: Types of gravitational phenomena utilized in wastewater treatment

(Reproduced from: METCALF & EDDY 2003. *Wastewater Engineering, Treatement and Reuse,* New York, MeGraw-Hill).

2.6.2 Secondary Treatment

The secondary wastewater treatment process also referred to as biological treatment, is used to remove soluble biochemical oxygen demand (BOD) that passes through the primary treatment process, and the continual removal of the remaining suspended solids. Secondary treatment refers to those treatment processes that use biological processes to convert dissolved, suspended, and colloidal organic wastes to more stable solids that can be either removed by settling or discharged to the environment without causing harm (Spellman, 2009).

The basic ingredients needed for conventional aerobic secondary biologic treatment are, the availability on may microorganisms, good contact between these organisms and the organic material, the availability of oxygen, and the maintenance of other favourable environmental conditions (for example, favourable temperature and sufficient time for the organisms to work) (Mackenzie L. Davis and David A. Cornwell, 2008). There are four methods used to achieve biological treatment, (1) activated sludge, (2) trickling filters, (3) Treatment ponds, and (4) rotating biological contactors. Activated sludge, trickling filters, and rotating biological contractors follow the normal primary treatment process, where ponds can be located anywhere with the treatment process. Most secondary treatment processes decompose solids aerobically producing carbon dioxide, stable solids, and more organisms (Spellman, 2009). The final step in the secondary treatment process is the disinfection of the effluent before discharge.

Activated Sludge

Activated Sludge is discussed in Chapter 5.

Trickling Filters

The trickling filter process involves an irrigation type sprinkler system known as a rotary distributer that sprays wastewater over a bed of course material or media as it moves above the surface of the trickling filter tank.

Treatment Ponds

The treatment ponds are a versatile method for treating wastewater, easy to build and manage, they can handle fluctuations in flow, and they can provide a treatment level that is at a much lower cost than a conventional process with highly purified effluent.

Rotating biological contactors

The rotating biological contactors (RBC) is a biological treatment process, that use the same attached growth theory as trickling filters. Still relying on microorganisms that grow on the surface of a medium, the RBC is instead a fixed-film biological treatment device, but the basic biological process is similar to that occurring in the trickling filter (Spellman, 2009). As the attached microbes pass through the reservoir, they absorb other organic compounds for oxidation (Davis, 2010).

Disinfection

Disinfection is the last step in the secondary treatment process and involves the addition of chlorine or ozone gas to the wastewater. The gas is injected into the wastewater as a disinfectant to kill off any of the remaining pathogens. The level of chlorination needs to be monitored and continually adjusted especially in the case where effluent is discharged into drinking water; because drinking water is further chlorinated at water works.

2.6.3 Advanced Treatment

The advance treatment process also known as tertiary wastewater treatment is incorporated into a wastewater treatment plant to remove pollutants that are not adequately removed by secondary treatment. According to Davis (2010) the need for treatment of wastewater beyond that which can normally be accomplished in secondary treatment is based on the recognition of one or more of the following:

1. Increasing population pressures result in increasing loads of organic matter and suspended solids to rivers, streams, and lakes.

2. The need to increase the removal of suspended solids to provide more efficient disinfection.

3. The need to remove nutrients to limit eutrophication of sensitive water bodies.

4. The need to remove constituents that preclude or inhibit water reclamation.

The secondary treatment process in most case is capable of removing the required amounts and concentration levels of BOD, suspended solids, and pathogens for the discharged effluent required by Government Environmental standards.

Filtration

Filtration uses two methods, granular and membrane filtration to remove the residual suspended solids that are left over from the secondary treatment process, including the unsettled microorganisms from the biological treatment process.

Absorption

The absorption process can be used to remove refractory organic compounds and soluble organic materials from the treated effluent that are resistant to biological breakdown processes. The refractory organics and soluble organics are detected as soluble COD in the effluent.

Extended Detention Time

The extended detention time is the simplest method for advanced treatment of wastewater. A separate settling tank or the settling tank in the secondary treat process can be used to allow the organics in the effluent that are light and require longer to settling time to settle.

Micro-screening

The micro-screening or micro-straining process uses a woven steel wire fabric mounted around the perimeter of a drum. Expected performance for suspended solids removal is 95 to 99%, but the typical suspended solids removal achieved with these units is about 55% (Spellman, 2009).

Chemical

The chemical treatment process uses chemical such as Lime, Aluminium sulfate, Aluminium salts, Ferric or ferrous salts, polymers and bio-additives, mixed with the wastewater as an advance treatment process to achieve high level effluent for reuse. The chemicals are used to remove biochemical oxygen (BOD), total suspended solids (TSS), Phosphorus, heavy metal, and the other materials that are not removed in the settled solids. The phosphorus and nitrogen removal processes will be discussed in further detail in a later chapter.

Sludge

The sludge or bio-solids are the mixture of solids and wastes that remain after the wastewater has passed through the different treatment phases. Raw wastewater, primary, secondary and advance treatment processes all produce waste sludge, which can be made up of as much as 97% water. According to Davis (2010) sludge requires further treatment before it can be ultimately disposed of.

2.7 Summary

Research has shown that there is numerous methods and configuration available when designing or upgrading a wastewater treatment process and plant. The major or critical factors that should be consider when designing a WWTP are the location of the site to local population, the size population to be serviced, the type of sewage to be treated, the level of treatment required by the governing bodies, the type of treatment process and equipment and the expected power consumed by the treatment process.

Many of the processes described above could be added to the current NWWTP if the type of wastewater treated by the site changed. But the design of the NWWTP is to operate as efficiently and cost effective as possible. Therefore any upgrade or changes to the NWWTP would need to follow those simple rules. Many of the treatment processes listed in this chapter can be ruled out as possible upgrades to the NWWTP, because of the type of waste the NTP treats. The SBRC estimates that the NTP treats 95% domestic waste and runoff water with the other 5% of waste received being form a number of different sources.

Chapter 3 Oxidation Ditch

3.1 Introduction

This chapter will investigate the oxidation ditch (OD) and the process employed at the NWWTP that utilizes the OD process. The first part of the chapter will give brief back ground on the what an oxidation ditch is and its purpose in secondary wastewater treatment. The chapter will then look at the history of the Nanango oxidation ditch as well as the history or origins of the modern day OD. This section will be followed by the theory behind the OD process . The chapter will then look at the design of the OD and the different configuration that are possible with a focus on the design of the Nanango OD. The final section of this chapter will be a summary of the OD at used at the NWWTP with any suggested improvements or enhancements that could be made to the OD to improve the process.

3.2 Background

The oxidation ditch is the simplest and most commonly used method of secondary wastewater treatment. Wastewater treatment processes that utilize oxidation ditches require little maintenance and are ideally suited to serve the treatment needs of small communities. Depending on the amount of wastewater and level of the treatment the site is trying to achieved, OD’s can require a large amount of land. The large foot print created by OD's generally means that treatment plants are located in areas removed from the local population. The OD alone is not enough to achieve secondary treatment it requires the addition of air or oxygen as food for the microorganisms to grow and agitation to promote flocculation. If the air or oxygen is not certificate enough to supply the required agitation to promote the flocculation of particles, mechanical devices are incorporated either as submerged or surface aerators.

The oxidation ditch at the Nanango wastewater treatment plant was built in 1984 as part of plant upgrade to handle the growing population for the South Burnett region due to the construction of Tarong Power Station and Meandu coal mine. The oxidation ditch is a signal channel oval or race track shape that is designed to handle a volume of the raw sewerage influent for approximately 2500 persons. If required it can also be used for extended aeration activated sludge process.

3.3 History

The oxidation ditch was developed during the 1950's at the Research Institute for Public Health Engineering (TNO) in the Netherlands as an easily operated and low-cost method of treating raw sewage emanating from small communities and industries. According to the United States Environmental Protection Agency (2000b) the oxidation ditch process was developed by Dr. Ir. A. Pasveer in Holland as a modification to conventional activated-sludge plug-flow process. Compared to the area required for the oxidation ditch process the conventional plug flow process utilises a long narrow tank that requires much less physical area to operate, but the concepts and theory for the treatment of wastewater are the same. The concept of the plug flow process involves wastewater that enters one end of the tank and exits at the other and relies on the velocity of the influent remaining at low constant flow rates while entering and travelling through the tank. By keeping velocity flow rate low and at a constant, allows sedimentation of solid particles of very small size to settle at the bottom of the tank through the force of gravity. Baffles are also utilized at the inlet to help control the flow rate and promote mixing. This phenomenon is known as the settling or sedimentation theory. Davis (2010) categorizes the sedimentation theory into four class : discrete particle settling, flocculants settling, hindered settling and compression settling.

For the purpose of this report we are only interested in discrete particle settling and flocculants settling. The discrete particle settling theory involves the settling of low concentration solids that do not interact or combine such as sand and grit while flocculants settling involves the particles the collided to form larger heavier particles. Both processes use the theory of sedimentation through different methods to achieve settling and particle separation of solids. They are removed from the bottom of the tank either by mechanically scraper or a draw off valve. The early plug flow process used oxygen from the atmosphere to aerate the influent within the tank through simple surface absorption. The plug flow method was limited, because only the top layer substrate of the wastewater receives oxygen.

The plug flow process was later improved by adding diffused air or mechanical aeration to the tank. According to Davis (2010) the oxygen demand in the plug flow process is at its highest in the first 20 percent of the tank because of substrate oxidation. Davis also (2010) states the plug flow process has problems with dissolved oxygen depletion, which will have a detrimental effects on the microbial population within the sludge, causing the production of organic acid and drops in pH levels. The oxidation ditch improved on the failings of the plug flow process while reducing the number of treatment processes required before and after the secondary treatment process while achieving higher levels of quality treatment effluent. The plug flow process generally involves grit removal devices, primary clarifier, and secondary clarifier along and the plug flow aeration tank, while oxidation ditch in its most basic form requires the a screen, oxidation ditch and secondary clarifier.

3.4 Theory

The theory behind the oxidation ditch process is based on an improvement to plug flow process. In the oxidation process, influent is continuously recirculating around a closed loop channel or channels creating better flocculation of organic materials and longer extended times for settling and separation of particles. The aeration process is generally carried out by mechanical aerators that are designed to mix the wastewater organics into a more homogenous substance also known as mixed liquor(ML), to supply oxygen used as food by the microbiological organisms, and to circulate the mixed liquor at low velocities of around 0.25 to 0.30 m/s to enhance satiability. The low velocities allows the mixed liquor to circulate the tank in 5 to 15 minutes, and the magnitude of the channel flow is such that it can dilute the influent wastewater flow by a factor of 20-30 (Metcalf and Eddy, 2003).

The dimension of the ditch or ditches incorporated in the treatment process depends on the area available at the proposed site and the type of treatment level that the OD is trying to achieve. Modification can be made to the oxidation ditch design to achieve further nitrogen and phosphorus removal. Through the addition of anoxic zones within the OD higher levels of biological nitrogen removal can be achieved in a single tank (Metcalf and Eddy, 2003). Along with the nitrogen removal and denitrification the oxidation ditch can be used to achieve biological phosphorus removal performance with low operational and maintenance costs. An oxidation ditch that is incorrectly designed for the treatment level required or for the type of wastewater being treated, it can hinder the treatment process.

3.5 Oxidation Ditch Design

All tho the design and structure of the oxidation ditch seems simple and uncomplicated. The design if incorrectly sized for depth or length can lead to undesirable odours, toxins, and incorrectly treated wastewater. The depth of the oxidation ditch is a very important parameter when considering the type of effluent treatment the site is trying to achieve. If the depth of the ditch is too deep or the length of the channel is too long, the settling of suspend solid and the mixture of oxygen becomes an issue. When influent particles are not given enough time to settle the turbidity of the wastewater can increase, which has an effect on the growth rate of the bacterial organisms. Poorly or incorrectly treated effluent will need to retreat either through chemical enhancement or recycling back through the system.

The bacteria and filamentous organisms, which can negatively affect the sludge and sludge settling can form, which intern increases the turbidity, total suspended solids and or increased bulking in the sludge. If the OD is too deep or too long for the aeration process, anoxic and anaerobic zones will form and if the process as a whole is not designed to control or correct this situation further loading, settling and organic bacterial problems can occur.

The material the ditch constructed from is another factor that needs to be considered when designing an oxidation ditch. If the material is not suited to the treatment process and the type of wastewater being treated, the material can break down allowing leakage into the surrounding soil contaminating the site. Undesirable bacteria can form and grow if the material contains pores or cracks, which become deficient of oxygen.

Case Study

One such situation was experienced in December 2000, at the Bonita Springs West Water Reclamation Facility where excessive bulking of sludge caused turbidity and bacterial problems. A study by Goodwin (2002) contributed several factors to the bulking sludge problems but one of the major contributing factor was the design of the ditch and the influent intake.

The ditch itself can be arranged in almost any configuration as long as it forms a closed circuit (William F. Ettlich, 1978). The most common ditch design is the oval or race track form as used at the Nanango plant. Figure 1 shows the basic oval shape ditch used at the NWWTP, there are three other possible alternative ditch configuration, a circle, ell, and horse shoe shapes all of which form a closed loop. In its simplest arrangement a single OD is used with an aerator or aerators that supply the required oxygen to the influent. The OD can also be designed and used as the final clarifier. To be used as a final clarifier the aerators are stoped and the raw sewerage either continues to enter the ditch or it is stored in a holding tank. Once solids have had time to settle, effluent is drawn off through a weir or valve and the cycle is repeated.

The two OD treatment process uses the same method for treatment as the single OD, but it incorporates two ditches that work in an alternating or intermittent operation. The process operates with one OD in the settling process while the second OD is receiving influent and the aerators are in operation. There can be many variation to this two ditch intermittent operation but the result is essentially the same (William F. Ettlich, 1978). The most common configuration used is the single oval OD with a final clarifier tank such as at the operation at the NTP. This process is operated as a continual flow basis, waste influent enters the ditch where it is mixed, aerator and solids are settled. The process can be used to withdraw the mixed liquor from the ditch, allowing damping of the influent flow and providing some equalization storage.

NWWTP Oxidation Ditch

The design of oxidation ditch at the Nanango plant is a simple oval shape with approximate dimensions of 54m in length and 15m wide, with a 40m long centre island running through the centre of the OD as shown in figure 1.

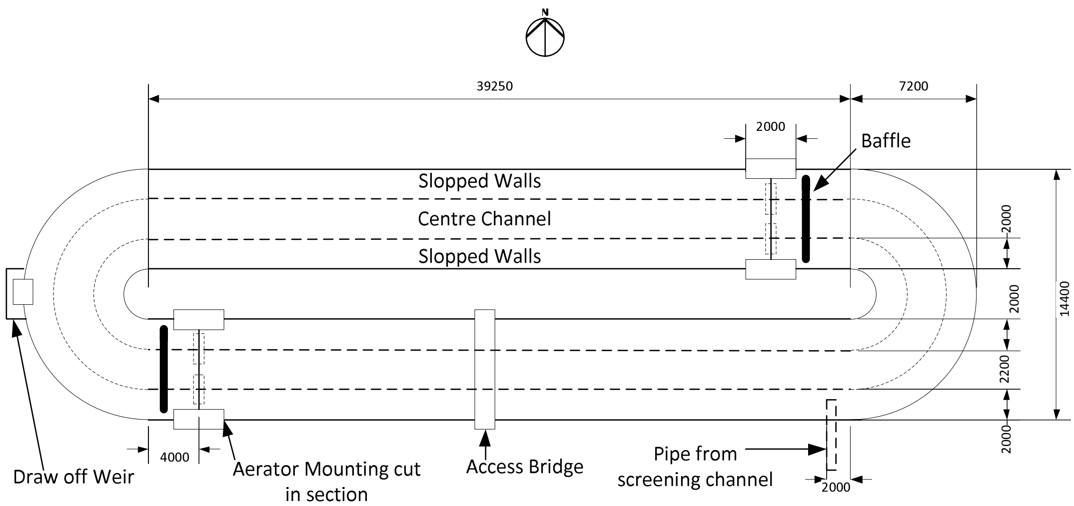

Figure 1: Top view drawing of the OD at the NWWTP

The island is used to create the closed loop and to support the mechanical aerators. The ditch channel is 2m deep, 6.2m wide with a 2.2m flat floor in the centre of the channel with walls at 45 degree slops on both sides of the channel floor shown in Figure 2. The rounded ends of the oval ditch are designed using trapezoidal shaped sections to create the curve for the banks. The OD is constructed from reinforced concrete with 75mm thick walls and base.

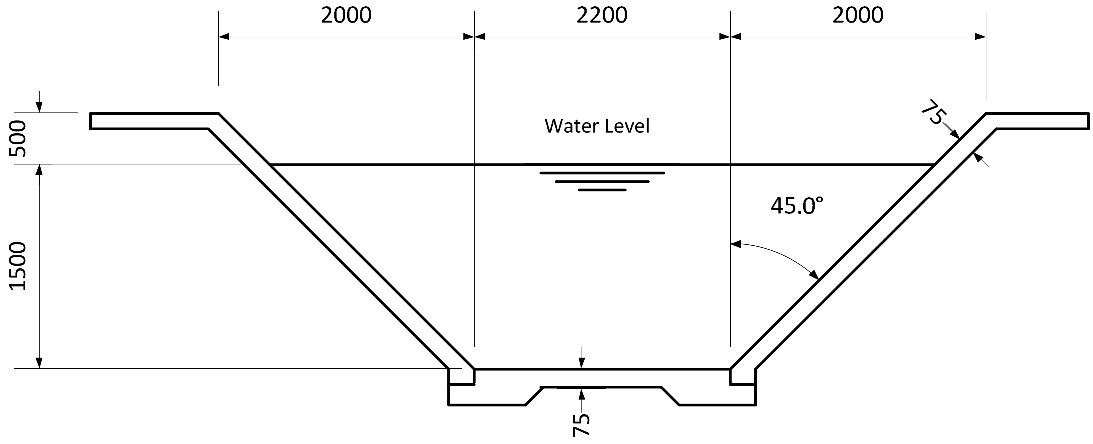

Figure 2: Dimensions of oxidation ditch

As shown in figure 1, at alternating ends of the OD are two cut in sections on the opposite sides of the channel that are used to mount the rotor motor and gear box assemble. The cut out sections are each supported by large concrete block which is used to support the weight of the rotors and the motor and gear box assembly shown in figure 3. The large concrete blocks are also used to absorb the vibration forces created by the rotating equipment. Baffles are installed below both sets of aerators in the direction of flow. The baffles are used to generate extra turbulence in the aerator mixing zone and to hinder the settling of the activated sludge on the bottom of the OD. The baffles deflect the mixing wastewater to the bottom of the OD, which force the activated sludge from the bottom on the OD mixing it with oxygen and other particles in the OD promoting the flocculation process.

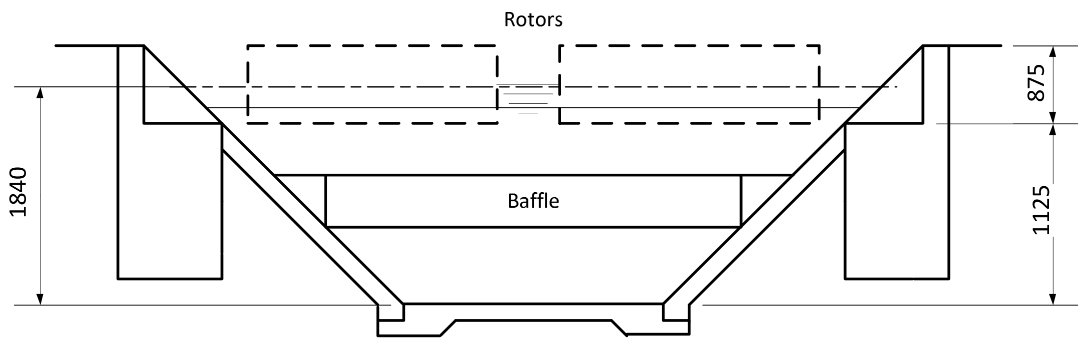

Figure 3: Location of rotors and baffle in oxidation ditch

In the case of damage to the OD or leakage through defects over time the base of the ditch sits on a 100mm thick sand base with a 0.2mm thick water proof membrane material between the concrete and sand shown in figure 4. The sand base and membrane material are a safety measure to prevent leaching of wastewater into the subsoil and surround environment. The maximum height that the wastewater can reach in the OD at the NWWTP is 1.84m. If the water level exceeds this height it will inundate the electric motors and gear boxes for the aerators, which will stop and damage the system.

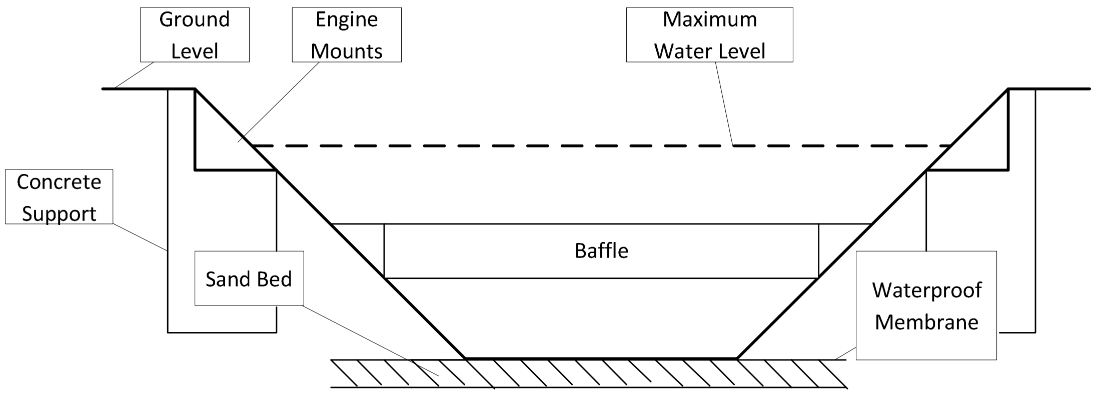

Figure 4: Location of sand barrier and membrane material

3.6 Summary

The current design and operation of the OD at the NWWTP is adequate and suited for the level of treatment the site is trying to achieve. As described the site operation manual in appendix C the NWWTP is an aerobic treatment process that use the OD for extended aeration for which the OD is ideally suited. There are no upgrades that can be performed to the OD to improve the current treatment process. The OD itself was described as been in good structural condition with no visual signs of damage to the inner surface of the OD.

There would be no issue with the design of the OD in future if the owners were to replace the current aerations with a floating aeration system. The cut in sections used to mount the motor and gear box assembly would create dead zones that could see a build up of waste particles in these sections that will receive no oxygen or mixing This could potentially create a toxic or harmful substance that could affect the treatment process or supply false readings to the testing process.

The only possible upgrade or improvement that could be designed into the OD at the NWWTP would be to the draw off weir. Even tho the draw off weir is a separate process it controls how the OD will interact with the other secondary treatment processes. The current weir could be replaced with a mechanically operated weir gate that could be integrated into a control monitoring system. This would remove any issue and/or mistakes made by operators who may miss judged the height of the wastewater or inflow level when setting the height of the water in the OD

Chapter 4 Aeration

4.1 Introduction

This chapter will investigate the processes of aeration, which is used to add oxygen and mixing to untreated wastewater. The first section of this chapter will give a background on what the aeration process entails and what the aerations process is trying to achieve in wastewater treatment. The next two sections in the chapter will look at the theory of aeration and equations used in the aeration process. It will than focus on how the aeration process controls the interaction between liquids and gases and what the controlling factors involved. The following sections of the chapter will looking at the types of aeration processes and equipment available and the aeration process employed at the NWWTP. The last section of this chapter will be a summary of the aeration process at the NNWTP compared to alternative aeration processes with recommendation on possible enhancement or replacement that could be made to the NWWTP aeration process.

4.2 Background

Aeration, also known as air stripping, mixes air with water to volatilize contaminants (turn them to vapour), which are either released directly to the atmosphere or treated and released (Lehr and Keeley, 2005). Aeration is used in wastewater treatment to remove volatile organic chemicals (VOC) and to promote the activate sludge process, by the supply oxygen and mixing to wastewater through mechanical or diffused aeration. The rate of removal of VOC and nutrients depends on the amount of air used, contact time, and temperature of the air and water.

The aeration process is one of the most important processes in wastewater treatment and for a simple secondary wastewater treatment plant it is the most important process. According to Mueller, Boyle and Popel (2002) the primary operational objective of the aeration process is to achieve an acceptable effluent quality while maximizing aeration efficiency. The aeration process is not primarily to just supply oxygen to the wastewater but also to promote and enhance the flocculation of the SS within the wastewater. As discussed in Chapter 2 the original plug flow process used to treatment wastewater in the past used oxygen supplied from the atmosphere with no means of mixing. This process lead to poorly treated effluent with oxygen only being supplied to the upper strata of the wastewater. The addition of mixing or agitation saw remarkable improvements in the quality of effluent being discharged, which saw the development of diffused and mechanical aeration processes.

The development of diffused and mechanical aeration systems improved the quality of wastewater but added the extra expense for the power need to operate the aeration equipment. According to a study by Rieger, Alex, Gujer and Siegrist (2006) the air supply systems or aeration processes are a major factor in energy costs and can account for as much as 60% of the total energy consumed by the site.

The diffused aeration process achieves high levels of quality treated effluent with excellent control over the process. But the diffuse aeration process requires the use of compressors which consume larger amounts of electricity. The compressors are used to force oxygen or air through pipe work that is located generally at the bottom of the aeration tanks, which requires extra force to be applied to the supply air to overcome the force of the wastewater at the bottom of the tank due to pressure. In most situation the diffused aeration process also requires the addition of mixers or blowers to help with the flocculation process, which adds even more power consumption to the process. Mechanical aeration also achieves high levels of quality treated effluent but can lack the control achievable with the diffused aeration. Mechanical aerators use motors and gear boxes to drive mixing devices such as brush and disk rotors, impellers and props. Air is generally supplied via the atmosphere through the agitation and mixing process. Oxygen can also be supplied via pure oxygen injectors or the addition on diffusers to the aeration tank.

4.3 Aeration Theory

The theory of aerating water involves the principle of mass transfer, where the moving of molecules or a mass is transported from one location to another through the use of force. In the case of wastewater aeration is achieved through the means of gravity and or mechanical devices. Mueller (2002) theories that the process of wastewater aeration is a relationship between the gas and liquid phase and the saturation concentration that each substance is able to absorb. Mueller described this process in wastewater treatment as a three stage process where the mass transfer process involves the transfer of gas or oxygen from the atmosphere or a pure oxygen supply into a fluid medium, or wastewater. The three stage process begins with the gas or oxygen molecules being transferred from the gas phase (oxygen) to the surface layer of the of the wastewater. Stage two occurs when the oxygen and wastewater establishes an interface at or near the surface of the liquid also known as the boundary where the gas and liquid molecules begin to interact. The final stage occurs as equilibrium between the oxygen and wastewater interface is reached and the oxygen begins to travel and dissipate into the wastewater being consumed by the microorganisms.

Davis (2010) uses the Lewis and Whitman method of a two-film theory to describe the mass transfer of gases. The theory describes two distinct films one made of the gas and the other made of the liquid with a distinct barrier between them. The theory divides the gas and liquid into four distinct areas the bulk gas, gas film, liquid film and bulk liquid as shown in Figure 5. This theory is also driven by the saturation concentration of the bulk liquid, where molecules will pass through the bulk gas, gas film, liquid film, and the bulk liquid when the saturation concentration in the bulk liquid is less than that of the bulk gas. The process can happen in reverse if the bulk liquid saturation concentration is higher than that of the bulk gas and the molecules move in the opposite direction. Both aeration theories use the same concepts and achieve the same results.

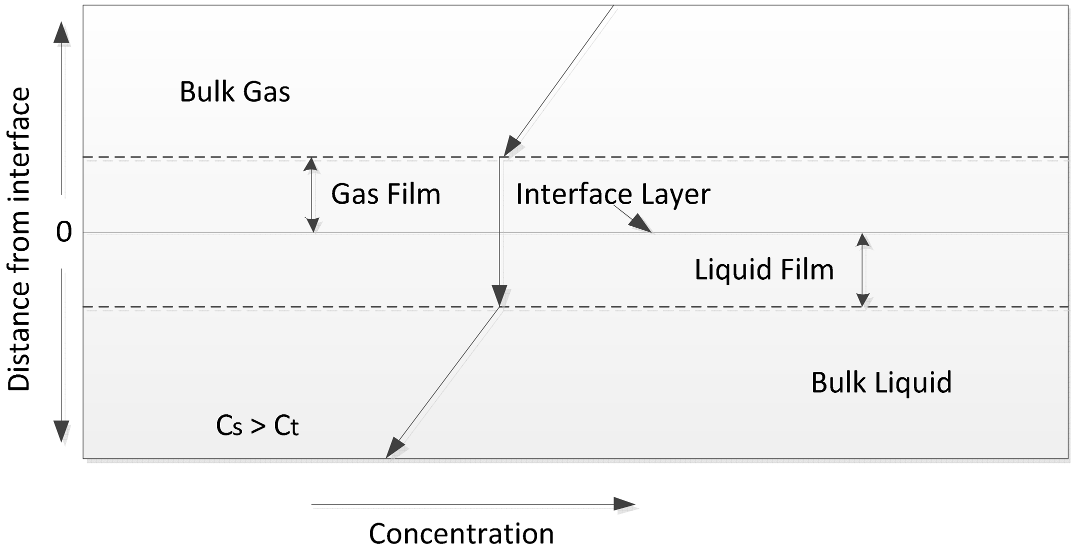

Figure 5: Gas and liquid interface.

(Reproduced form Mueller, Boyle & Popel, Aeration and Pratice, 2000).

The prime factor that governs the transfer of atmospheric oxygen into raw sewage is the competition between the microorganisms for food or substrate. The microorganisms or bacteria according to Davis (2010) will take on a predator pray relationship with the species of bacteria that has the ability to metabolize the substrate quicker becoming the dominate species thus creating the larger mass. When the substrate is depleted the predator population or the bacteria that can feed on the original dominate species becomes the dominate bacteria. This process is a natural occurring cycle in water but it becomes an important process to control in wastewater due to the high level of constitute and organics within the wastewater. The use of forced aeration via diffused and mechanical aerators are used in secondary or biological treatment to assist and maintain the growth of the microorganisms that are used to break down the organics into gasses and protoplasm.

4.4 Aeration Calculation

This section introduce the basic development for the equations used in the calculation of the transfer of oxygen into water and how they can be adapted to wastewater.

The simple mass transfer model for a gas into a liquid is:

$$\frac{C_s - C_t}{C_s - C_0} = e^{-(k_L a)t}$$

Where $K_L a$ is the volumetric transfer coefficient in units s^{-1}
C_t is the concentration in the bulk liquid at a time t, mg/L
C_s is the concentration in equilibrium with gas as given by Henry's law
$C_0$is the initial concentration

The Lewis and Whitman adapted equation for the mass transfer rate of oxygen into water;

$$\frac{dC}{dt} = K_L a(C_s - C_t)$$

The Lewis and Whitman equation uses the saturation concentration theory, which is defined as amount of liquid or gas that can be absorbed by one substance into another until equilibrium is reached between the two substances and they can no longer absorb in to each other. The Lewis and Whitman equation is not enough to calculate the actual oxygen transfers rate for the aeration of wastewater. The transfer of oxygen into any fluid is not governed by the saturation concentration level only but also by the ability of the fluid to absorb the gas, known as the diffusivity. Diffusivity and saturation concentration are both evaluated by the temperature of the oxygen deficit wastewater, where the saturation decreases with the increase in temperature and diffusivity increases with temperature.

The equation for diffusivity of a liquid at different temperatures is calculated from the diffusivity of the liquid at 20°C;

$$D_{t,°\mathrm{C}} = D_{20°\mathrm{C}}\theta^{t-20}$$

The diffusivity equation represents the overall liquid film coefficient or the volumetric transfer coefficient $K_L a$ at the temperature (T) of the wastewater compared to the lab tested results at 20°C.

$$K_L a_{(T)} = K_L a_{(20°\mathrm{C})}\theta^{T-20°\mathrm{C}}$$

Where $K_La_{(T)}$ is the oxygen mass transfer coefficient at temperature T, s^{-1}
$K_La_{(20^oC)}$ is the oxygen mass transfer at 20°C, s^{-1}
T is the temperature of the wastewater
θ is the dimensionally not homogeneous requiring a temperature in °C.

The value of θ is commonly taken as 1.024 (ASCE, 1993; Jensen, 1991). Davis and Cornwell (2008) list the values of θ range from 1.015 to 1.040, which varies with lab conditions. Taken the equation for the transfer of oxygen into clean water and replacing K_La with $K_La_{(T)}$ for the coefficient of mass transfer for the wastewater and adding the affect of the microorganism on the transfer of the oxygen equation becomes.

$$\frac{\mathrm{dC}}{\mathrm{dt}} = \mathrm{K_L}a_T(\mathrm{C_s} - \mathrm{C}) - \mathrm{r_M}$$

Where *C* is the concentration of the oxygen in the wastewater.
$\mathrm{r_M}$ is the rate of oxygen used by the microorganism.

The goal of aeration is to maintain the level of oxygen in the aeration tank at 1 to 3 mg/L, keeping the $\frac{\mathrm{dC}}{\mathrm{dt}}$ equal to zero, which means the concentration of oxygen (C) in the tank will be constant.

But this equation only accounts for the transfer rate of oxygen in to wastewater from the atmosphere. It fails to factor in the effects of the mixing intensity (α) of diffused or mechanical aerators, the geometry of the aeration basin, the characteristics of the wastewater (β), and the fouling of equipment (F).

$$a = \frac{C_s(wastewater)}{C_s(tap\ water)}$$

Where α is the correction factor for the mixing intensity and tank geometry and is used to estimate the actual K_La in the system. Typical values of α are 0.2 to 0.5 for conventional BOD oxidation, 0.4 to 0.7 for nitrification only, and 0.5 to 0.75 for nitrification-denitrification (Rosso and Stenstrom, 2007). Eddy and Metcalf (2003) used the values for diffused and mechanical aeration equipment with the ranges of 0.4 to 0.8 and 0.6 to 1.2, respectively.

$$\beta = \frac{C_S(wastewater)}{C_S(tap\ water)}$$

And β is the correction factor used to correct the oxygen transfer for the differences in oxygen solubility due to constitutes in the water such as salts, particulate matter, and surface active substances. According to Davis (2010), Eddy and Metcalf (2003) the value of β can range from 0.7 to 0.98 with 0.95 commonly used for wastewater.

The interrelationship between these factors and temperature, elevation above sea level, and the depth of diffusers is expressed as follows (Metcalf & Eddy, 2003):

$$AOTR = SOTR\left(\frac{\beta C_{\bar{s},T,H} - C_L}{C_{s,20}}\right)(1.024^{T-20})(\alpha)(F)$$

Where AOTR = the actual oxygen transfer rate under field conditions, Kg O_2/h
SOTR = the standard oxygen transfer rate in tap water at 20°C, and zero dissolved oxygen, Kg O_2/h
β = the salinity-surface tension correction factor
$C_{\bar{s},T,H}$ = the average dissolved oxygen saturation concentration in clean water in aeration tank at temperature T and altitude H, mg/L

$$= (C_{\bar{s},T,H})\frac{1}{2}\left(\frac{P_d}{P_{atm,H}} + \frac{O_t}{21}\right)$$

For surface aerators $C_{\bar{s},T,H} = C_{s,T,H}$

The terms in brackets when multiplied by one-half represents the average pressure at the mid depth and accounts for the loss of oxygen to biological uptake. If the biological uptake is not considered, then the following expression can be used:

$$= (C_{\bar{s},T,H})(\frac{P_{atm,H}P_{w,mid\ depth}}{P_{atm,H}})$$

$C_{s,T,H}$ = oxygen saturation concentration in clean water at temperature T and altitude H

P_d = pressure at the depth of air released, kPa

$P_{atm,h}$ = atmospheric pressure at altitude H, kPa

$P_{w,\ mid\ depth}$ = pressure at mid depth, above point of release, due to water column

O_t = percentage of oxygen concentration leaving the tank, usually 18 to 20 percent

C_L = operating oxygen concentration, mg/L

$C_{s,20}$ = dissolved oxygen saturation concentration in clean water at 20°C and at 1 atm, mg/L

T = operating temperature, °C

α = oxygen transfer correction factor for wastewater

F = fouling factor, typically 0.65 to 0.9

The calculated AOTR is used to estimate the actual amount of oxygen being transferred into the wastewater while the SOTR value is generally supplied by the manufactory of the aeration equipment. The SOTR value for aeration equipment is tested and rated in libratory condition for clean water at 20°C. The SOTR value supplied by manufactures for aeration equipment is used as a selling point and before deciding or purchasing aeration equipment the AOTR should be calculated for the given condition of the treatment plant. The fouling factor is of particular importance, varying with the type of equipment employed in the treatment process.

The above set of equations allows treatment plant designers to compare different types of aerations equipment. From a calculated set of AOTR values plant designers can also choose the process or level of treatment the site will be aiming to achieve and match it with the most efficient or cheapest to operate alternatives. The different types of aeration equipment available are not a one size fits all and a process generally cannot be changed to match a single equipment change. Therefore selecting the right equipment for the treatment process becomes vital to the design or even the upgrade of a treatment plant and process.

4.5 Types of Aerators

The mechanical surface aerators whether vertical and horizontal operate in the much in much the same manner. Both methods utilize oxygen supplied from the atmosphere to mix with the influent wastewater. The mechanical devices add addition oxygen to the wastewater through turbulence, water spray and jets. The turbulent mixing force allows the oxygen gas molecules to be pushed further into the substrate, allowing more oxygen to be transferred into the wastewater. The additional mix also promotes the flocculation of the mixed liquor suspended solids (MLSS) and to recirculate the activated sludge from the bottom of the aeration tank. This prevents sludge bulking and further enhance the flocculation of the MLSS.

The equipment used in the aeration process as discussed earlier can be divided into two process type; mechanical and diffused devices. Both process operate using different methods, conditions and equipment to ultimately achieve the same end results. The result that they are trying to achieve is a quality treated effluent that meets the require discharge levels for the sites issued permit in the most efficient method possible. Table 2 is reproduced form Eddy and Metcalf (2003) and gives a good over view of the commonly used devices in diffused and mechanical wastewater aeration. The table from Eddy and Metcalf (2003) divides the aeration process not into diffused and mechanical aerators but into two different categories, submerged and surface aerators. Even tho Eddy and Metcalf divide the aeration process concepts into the submerged and surface aeration for the purpose of this project they will be divided into the diffused and mechanical processes. The mechanical devices used in the submerged or diffused aeration are primarily used for additional mixing. In some cases compressed air or pure oxygen is supplied to the submerged mixers to help enhance the aeration process or as a method of controlling the aeration process.

Classification	Description	Use or application
Submerged: Diffused air		
Fine-bubble (fine pore) system	Bubbles generated with ceramic, plastics, or flexible membranes (dome, tubes, disks, plates, or panel configurations)	All types of activated-sludge processes
Coarse-bubble (nonporous) system	Bubbles generated with orifices, injectors and nozzles. or shear plates	All types of activated-sludge processes, channel and grit chamber aeration, and aerobic digestion
Sparger turbine	Low-speed turbine and compressed-air injection	All types of activated-sludge process and aerobic digestion
Static tube mixer	Short tubes with internal baffles designed to retain air injected at the bottom of tube in contact with liquid	Aerated lagoons and activated-sludge processes
Jet	Compressed air injected into mixed liquor as it is pumped under pressure through jet device	All types of activated-sludge processes, equalization tank mixing and aeration, and deep tank aeration
Surface:		
Low-speed turbine aerator	Large-diameter turbine used to expose liquid droplets to the atmosphere	Conventional activated-sludge processes, aerated lagoons, and aerobic digestion
High-speed floating aerator	Small diameter propeller used to expose liquid droplets to the atmosphere	Aerated lagoons and aerobic digestion
Aspirating	Inclined propeller assembly	Aerated lagoons
Rotor-brush or rotating-disk assembly	Blades or disks mounted on a horizontal central shaft are rotated through the liquid. Oxygen is induced into the liquid by the splashing action of the rotor and by exposure of liquid droplets to the atmosphere	Oxidation ditch, channel aeration, and aerated lagoons
Cascade	Wastewater flows over a series of steps in sheet flows	Post aeration

Table 2: An over of mechanical and diffused aeration equipment

(Reproduced form Eddy and Metcalf, 2003, *Wastewater Engineering, Treatment and reuse*, McGraw-Hill)

Diffused Aeration

Diffused aeration uses pressurized air or pure oxygen released as bubbles from diffusers located at the bottom of a tank, ditch or lagoon. The pressurized air is supplied by pressure vessel using compressors to supply and maintain the pressurized air to the diffusers while the pure oxygen is supplied from gas cylinders. The air released is generally classed in two categories fine bubble and course bubble. Eddy and Metcalf (2003) further defined the diffused air processes into three categories: (1) porous or fine-pore diffusers, (2) nonporous diffusers, and (3) other diffusers such as jet aerators, aspirating aerators, and U-tube aerators (Table 3 list the different types of air diffusers). All three diffused air processes involve the same basic concept. Air is released near the bottom of the tank as air bubbles rises they quickly through the water to the surface. The rising bubbles cause the surrounding water and organic material to be pushed around, creating a turbulent mixing force. The mixing force allows the oxygen to be dissolved into the wastewater where it is used as food by the microorganisms within the wastewater. The microorganisms use and the oxygen to help metabolise the organics within the wastewater into atmospheric gases and settable solids. In most wastewater treatment application the diffused aeration process use a combined system consisting of the aerator piping system or porous media material and a mechanical mixing device that produce large volumes of low pressure air to promote the mixing of the air and particles.

Type of diffuser or device	Transfer efficiency	Description
Porous		
Disk	High	Rigid ceramic disks mounted on air-distribution pipes near the tank floor
Dome	High	Dome-shaped ceramic diffusers mounted on air-distribution pipes near the tank floor
Membrane	High	Flexible porous membrane supported on disk mounted on an air-distribution grid
Panel	Very-high	Rectangular panel with a flexible plastic perforated membrane
Nonporous		
Fixed orifice		
Orifice	Low	Devices usually constructed of moulded plastic and mounted on air-distribution pipes
Slotted tube	Low	Stainless-steel tubing containing perforations and slots to provide a wide band of diffused air
Static tube	Low	Stationary vertical tube mounted on a basin bottom and functions like an air-lift pump

Table 3: Types of diffused aeration devices

(Reproduced form Eddy and Metcalf, 2003, *Wastewater Engineering, Treatment and reuse*, McGraw-Hill)

The efficiency of oxygen transfer depends on many factors, including the type, size, and shape of the diffusers; the air flow rate; the depth of submersion; tank geometry including the header and diffuser location; and the wastewater characteristics (Metcalf and Eddy, 2003). The diffused aeration process is prone to fouling due to clogging of the pores which reduces the efficiency. But according to Davis (2008) diffused aeration has the advantage over mechanical aeration in cold climates, because the air adds heat to the system, and the overall heat loss is less because of a smaller degree of surface disturbance. The diffused air process is rarely used in an OD setup because the ditch is not deep enough for the air bubbles to reach terminal velocity. Diffused air is generally incorporated into aeration, fluctuation, and maturation ponds or tanks with depths over 4 meters where the bubbles have time to reach terminal velocity.

Mechanical Aeration

The mechanical aeration process uses mixing devices driven by motors and gear boxes to agitate and supply air to wastewater influent. Mechanical aerators are commonly divided into two groups based on major design and operating features: aerators with vertical axis and aerators with horizontal axis (Metcalf and Eddy, 2003). Each group of mechanical aerators can be further broken down to either surface aerators or submerged aerators. Submerged aerators which also includes submerged blowers as described earlier are mainly used as mixers for the diffused aeration process. Although they can be used as standalone aeration process with the addition of compressed air or pure oxygen. These units are seldom used as dedicated aeration systems and according to Eddy and Metcalf they lack the necessary range of flow rates and pressures needed in the wastewater treatment process and require additional methods for controlling the speed of the motors.

Vertical and horizontal aerators can be installed in a number of methods and configuration. Vertical aerator units can be installed as straight vertical shaft or an angle vertical shaft mixer. They can be mounted onto floating pontoons structures, access bridges, directly onto aeration structures, or installed with specially designed frames and supports. Although aerators with shafts that are mounted on an angle are not technically vertical they are still classed as vertical aerators for industry purposes and for the purposes of this project the term "vertical mounted" will cover both units. Vertically mounted aerators operate in the exact same method as boat motors. The use impellers and props attached to the end of the shaft to churn the wastewater down, which creating large amounts of turbulence that propagates the wastewater to the surface completely mixing the substrate. The force of the rising water creates waves on the surface that interact with the oxygen in the atmosphere improving the transfer process. A variation to the impeller mixer is a screw or auger scooped impeller that is vertically straight mounted onto a floating platform. It use low trajectory to force the wastewater up the vertical shaft onto a deflector plate that pushes the wastewater down and creates a turbulent waves to promote the aeration.

Vertical mechanical aerators are very flexibly and efficient method of aerating wastewater. Vertical aeration units have the ability to operate in vastly changing treatment conditions. In most situation the length of the shaft can be adjusted to suit the depth of the wastewater, the type of impeller or prop can be changed to suit the level of treatment required and pontoon units can be moved to different location. The units can be designed with variable speed drives (VSD) and/or two impellers, two props or a combination of both. The double mixing units can be operated as a complete mixing and aeration process or as just a straight mixing unit for an anoxic treatment process.

Horizontal mechanical aerators methods of installation are not as varied as vertical aerators but they can offer flexibility to the treatment process. Horizontal aerators are generally installed in oxidation ditches and long channel aeration tanks perpendicular and at the full width of the channel walls. They can be mounted directly onto the channel walls via mounting brackets or specially designed structures or they can be installed onto floating pontoons. The horizontal aerators are designed in one of two ways as either disc rotor or brush rotor assemblies. The disc aerators are wafer-thin circular plates (typically about 1.5 m [5 ft] in diameter) and submerged in the water for approximately one-eighth to three eighths of their diameter (James A. Mueller et al., 2002). The discs have nodes or nodules on the disc face to help left extra wastewater from the OD, pushing the wastewater around the channel, creating turbulence and water spray to enhance mixing and aeration. The horizontal brush rotors operate much like the paddles used on old paddle streamers. They are designed with blades or scoops that are used to churning the water, which creates turbulence, water spray and a pushing force that circulates the wastewater particles or suspended solids around the channel.

Aerator Motors

The horizontal and vertical aerators are all driven by electric motors and in many case horizontal aerators require the addition of a belt, chain, or direct drive gear boxes to reduce the operating speed. The electric motors in particularly old electric motors will operate at only one speed and will be drawing the maximum amount of power required to operate. The power drawn by the motors will not be the power delivered to the aerators due to losses through the motor windings, couplings pulleys, belts, chains, gears and gear boxes. In particular the motors that utilizes gear boxes can be wasting large amounts of electricity through the number of gears within the gear box, the size of the gears and the number of teeth in contact between the meshing gears. Losses of up to 50 percent can be experienced from the supplied power to the delivered power. The power consumed or supplied to the aerators is generally supplied through mains power from the local power grids. Therefore controlling the power consumed becomes critical but also very difficult to reduce with old equipment without replacing.

As will be discussed in Chapter 7 a control and monitoring system can increase efficiency and reduce power used by the treatment process through controlling the electric motors. This can be achieved by two methods, by installing sensors to control the aerators to operate only when the process requires, or they can be fitted with variable frequency drives (VFD) also know as variable speed drives (VSD). The VFD units are an additional device that can be installed onto the electric 3 phase motors that change the frequency of the motor. Changing the frequency of the motor changes the speed at which the motor rotates but VFDs are limited to 3 phase motors. There are some alternative methods of suppling power to mechanical and diffused aerators.

Treatment plants with large foot prints or surrounding land that has been declared an exclusion zone due to the treatment plant, are being turned into mini solar farms. The power supplied from the solar panels is either being used directly by the plant or supplied back to the power grid for credit towards power being consumed from the grid. There are also mechanical surface aerators that are operated using solar planes that are mount directly onto the aerators and/or the pontoons. Some treatment plants operators are designing or redesigning their wastewater treatment facilities to utilize the waste sludge as a fuel source. The waste sludge is pumped into a bladder where it is allowed to break down creating methane gas, which is used as a fuel to power generators, which operate the aerators or other processes within the system.

4.6 Nanango Aerators

The aeration process employed at the NWWTP is a mechanical aeration system that consists of two sets of horizontal brush rotors that mounted above an oxidation ditch. The rotors are located at alternating ends on either side of the ditch on concrete supports. At maximum immersion depth of the rotors is 200mm in to the wastewater. Each rotor assembly consists of two 2m long TNO cage brush rotors. The four rotors operate individually and are driven by a Toshiba 5.5KW motor, with a full load current of 11.1 Amps and an operational speed of 1440 RPM. The electric motors are connected to the rotors through a reduction gear box which reduces the rotors down by a ratio of 20:1, slowing the rotor speed to 72 RPM. The aeration system is designed to operate three rotors as duty rotors and the fourth is a backup or stand by rotor as the system requires. The rotors are controlled by a simple timing circuit located in the main switch board. The site operators are responsible for programming or setting the timer that has a start and stops the aeration function.

The design of the NWWTPs' aeration process, lacks control over the aeration process which could be a contributing factor to the poor plant and treated effluent results being recorded by the site operators. In particular the process has little control over the amount of air that is supplied to the wastewater, the amount of delivered power that is transferred and used in the physical air and mixing processes and the operating condition the aerators are exposed to. These issues and problems can all be contributed to the lack of control that the operators have over the process. The lack of monitoring and recording of the processes data is also a serious problem.

The results for the aerator running hours and the tested level of dissolved oxygen listed for the same day are listed in Appendix D Table 15. The comparison between the results are very inconsistent . The amount of oxygen being supplied by the aerators for the aeration process cannot be linked to the level of aerobic treatment or recorded DO levels for that period of aeration. Figure 6 is a plot of the recorded DO levels for the NWWTP OD between 11/09/2009 to 21/09/2009.

Comparing the lines plots in figure 6 the statement can be made that the aeration process and DO results are not connected. This statement can be justified but comparing the results for the period between the 4/11/2009 to 20/11/209 where the aerators are in operation for between 37 to 30 hours while the DO concentration levels within the ditch drops. This contradicts the research already presented in the early in this chapter that increasing the oxygen delivered should increase the DO concentration levels. During this period the aerators are operating a fairly constant daily running hours. The DO concentration levels during this period spike with a DO level above 3.0mg/L but before this is at 0.2mg/L. During this period the aeration operating hours where constant this would lead to the statement that there is no connection between the aeration hours and the tested DO levels and the aerators may not be in contact with the wastewater.

The plot also contradicts this statement where around the 19/10/2009 as the aerators operating hours increased so did the tested level of DO concentration increased. There is no explication recorded on the daily record sheets as to why there was a large difference between the aerator operating hours and the tested DO levels. This could be contributed to operator error.

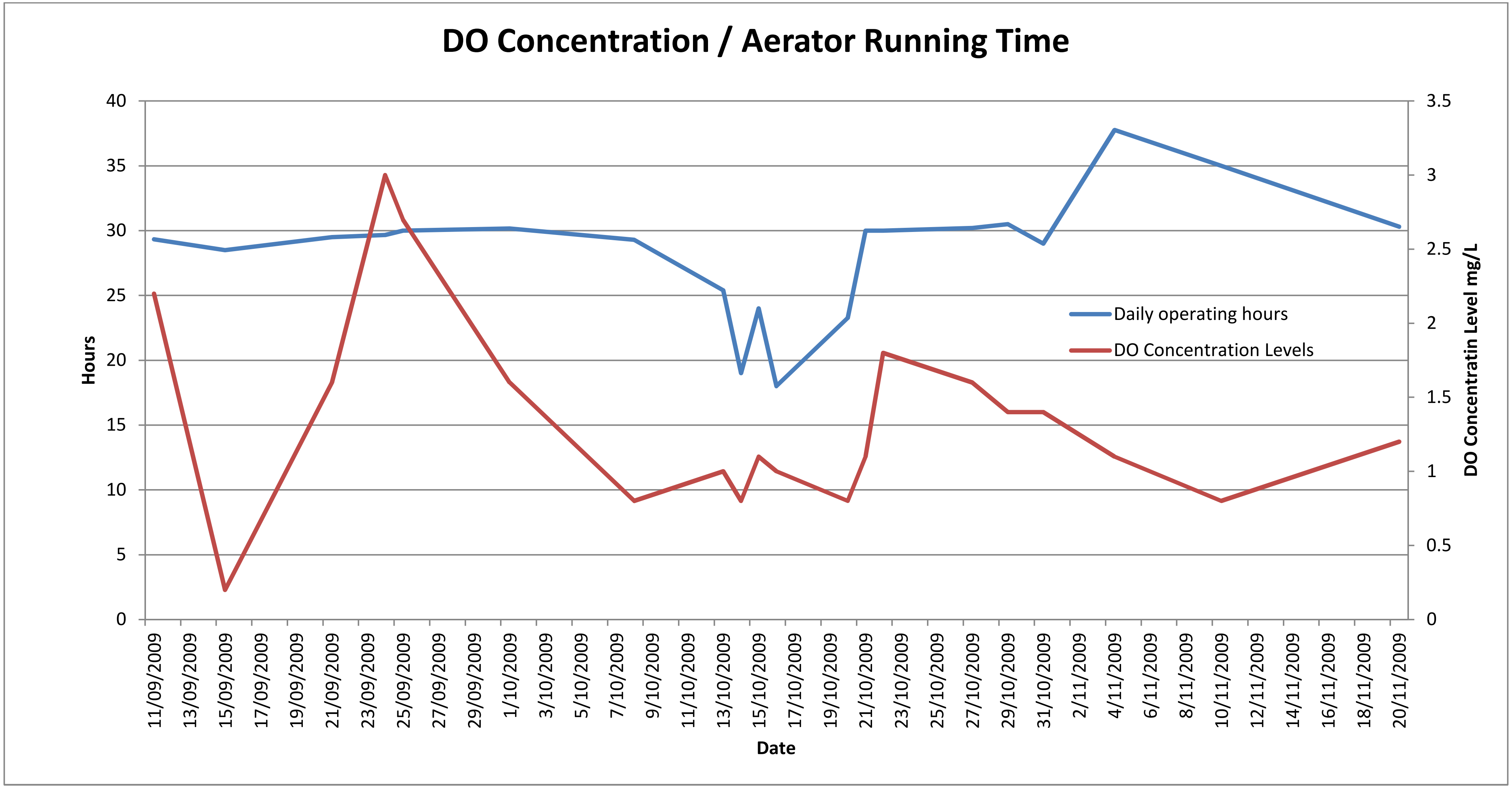

Figure 6: The plot DO Concentration compared to the aeration operating hours within the OD between 11/09/2009 to 20/11/2009.

The data in Appendix D shows that the aeration process can operate between 18 to 58 total hours on a daily average and these values were taken for 2 and 4 aerators operating at the same time respectively. The data also shows that the aerators can operate in any configuration of 2, 3 or 4 units depending on how the operate set the process. The aerators according to the operational (Appendix B) are capable of delivering 7.5Kg of O^2 per hour pre rotor. For the minimum and maximum run hours recorded in appendix D, would equates to a;

Minimum amount of oxygen delivered is; 7.5 x 18 = 135Kg of O2 per day

Maximum amount of oxygen delivered is; 7.5 x 58 =435Kg of O2 per day

The theoretical maximum power consumed by the brush rotors, ignoring losses from the gearbox, couplings, contact loss, motor efficiency and performance efficiency would be calculated at for the maximum and minimum recorded hours.

Minimum amount of power delivered is; 5.5kW x 18 = 99kWh

Maximum amount of power delivered is; 5.5kW x 58 = 319kWh

But this are untrue values because motors cannot operate a 100%, that is 100% of the power delivered to the motor is not turned into work. Using Tyco's specification for motors of the same design it can be assumed that the motors have an efficiency of 85% and a power factor (pf) of 83% therefore power consumed by the motors under normal operation will be;

Minimum amount of power used is; 140kWh

Maximum amount of power used is; 452kWh

Using the maximum and minimum power assumed values and the Queensland Governments suggested electricity cost of 15.125c/kWh the aerators are costing between;

Minimum daily operating cost; 140kWh x 15.125c/kWh = $21.18 per day

Maximum daily operating cost; 452kWh x 15.125c/kWh = $68.37 per day

The power used and the operating cost for the minimum and maximums are related to tested dissolved oxygen levels of 0.5 mg/L for the minimum and 1.6mg/L for the maximum. If the calculated figures above where used to describe the power used to treatment level achieved at the NWWTP process would be described as work as the process operation manual states. This statement would be incorrect and a small representation of what is actually happening at the NWWTP.

Taking the supplied data and looking further at the recorded data in particular at the recorded DO levels compared to the total daily operating hours, the data shows that the aerators can operate for 55 hours with a tested DO level of 0.2mg/L. There are many of these in-discrepancies between the DO level and the level of aeration delivered to the wastewater. The values are well below the sites own recommended DO levels for the oxidation ditch as stated in the operating manual. Reviewing the data further shows that the wastewater inflow DO readings can be much higher than that recorded in the OD. Table 4 is extracted from Table 15 in Appendix D and clearly shows that the raw sewage DO valve is higher than that within the OD and there is correlation between the aerators running hours and the DO level.

		Dissolved Oxygen			
Date	Total Hrs	Raw Sewage	Aeration Tank	Clarifier Effluent	Final Effluent
7/06/2010	33	1.9	1.3	1	1.5
8/06/2010	24	2	1.2	0.5	1.5
9/06/2010	24	1.9	1	0.8	1.6
10/06/2010	26	0.2	0.4	1.3	1.6
11/06/2010	24	1.4	1.1	1	1.6

Table 4: Information extract from Table 15 in Appendix D

Table 5 and 6 are also extracted from Table 15 and Appendix D and they also show that the tested DO results the aerators running time have no direct affect on each process. The results would lead to the assumption that the aeration process at the NWWTP is not capable of achieving the required treatment level and the aerators should be changed immediately.

		Dissolved Oxygen			
Date	Total Hrs	Raw Sewage	Aeration Tank	Clarifier Effluent	Final Effluent
21/06/2010	24	1.6	1.1	0.7	1.5
22/06/2010	25	1	0.4	0.5	1.5
23/06/2010	26	0.5	0.1	0.8	1.8
24/06/2010	23	1.5	0.5	1.1	1.6

Table 5: Information extract from Table 15 in Appendix D

Date	Total Hrs	Raw Sewage	Aeration Tank	Clarifier Effluent	Final Effluent
7/12/2010	46	0.4	0.1	0.2	1.3
8/12/2010	47	0.5	0.1	0.2	1.3
9/12/2010	46	0.7	0.3	0.3	1.3
10/12/2010	55	0.2	0.2	0.2	1.4

Table 6: Information extract from Table 15 in Appendix D

These results would make it impossible to make any calculation to compare the power used to the oxygen supplied and the efficiency of the NWWTP. The recorded data from the NWWTP is to inconsistent, there is large gaps between testing days and the test and recorded results contradicts all the studies, research papers and text books available on wastewater treatment. If the aerators are operating for the recorded hours and if they were making correct contact with the wastewater then it would be expected that the DO level would rise, which is not experienced at the NWWTP on a regular bases. This should lead to the question of what is the aeration doing or not doing and what could be done to rectify the situation.

There would be no advantage to making a knee jerk reaction and replace the current aerators if the problem with the aeration process is not the aeration equipment but is another contributing factor. An investigation should be carried out to identify the key elements of the aeration process, which could include;

- Physically observing the aeration process to determine if the aerators are making full, some or no contact with the wastewater within the ditch.
- Are the aerators actually running for the correct set time or does the time circuit need to be recalibrated.

- Testing of the DO levels and any other test should be carried out over a extended period so that the operates can obtain a picture of what the aeration process is doing.
- Has the bacteria needed in the treatment process in the activated sludge and wastewater die off to a level where it needs to be replaced.

4.7 Summary

It is the opinion of the author that any statement or assumption made about the NWWTP aeration process or treatment process as a whole would be incorrect if based solely on the recorded data from the daily report sheets. The daily report sheets lack enough important information about the weather conditions, temperature of the wastewater compared to the ambient, location of the DO testing and the time during the day the aerators are running. Also whether the aerators are running in intervals of 2 hours every few hours or are they running continuously. The NWWTP has very little process control outside what the operators set when they are no site. The monitoring system employed is also very poor with the test results only being carried out once per day and only in the morning. It is from these tests that the treatment process is set and left to operate until the next site visits. There are no alarming system to warn if the process has failed or is not running correctly.

Table 15 in Appendix D shows that for long durations the NWWTP as a whole operates below its own stated required DO levels. The process will not be operating as an aerobic treatment process for which it is designed. Instead the treatment process could be operating in an anoxic or even an anaerobic processes. This statement could be justified by the recorded DO levels for the wastewater inflow channel where the level of the DO was recorded at 0.9mg/L while the OD, DO level was recorded as 0.2mg/L. There was sufficient improvement to the DO after the period of aeration, which can lead to even more assumptions being made about the treatment process, the testing process or the data recorded, and the operators.

Chapter 5 Activated Sludge

5.1 Introduction

This chapter will investigate the activated sludge process and its importance to the secondary treatment process and in particular its importance to the NWWTP. The first section of the chapter will give a back ground on what activated sludge is and how the process is incorporated into the NWWTP. The focus of the following sections in this chapter will turn to the activated sludge and what it consists of, how the activated sludge is created and the chemical reaction achieved through the activated sludge process. The final sections with look at the methods of controlling activated sludge and methods of improving the activated sludge process with particular focus on the NWWTP.

5.2 Background

The history of activated sludge dates back to the 1880 and the work performed by Dr. Angus Smith, who investigated the effect aeration had on wastewater. According to Lee and Lin (2007) the activated sludge process was first used in Manchester, England and is perhaps the most used biological treatment process for secondary treatment of wastewater worldwide.

Activated sludge is the product of the biological or secondary treatment of wastewater. The activated sludge process derives its name from the biological mass formed when air is continuously injected into the wastewater (Davis, 2010, p. 23-3). Metcalf and Eddy (2003) have classified the biological treatment process as aerobic and anaerobic suspended growth, attached growth, and a various combination thereof. As describe in Chapter 6, microorganisms break down the organics in wastewater and it is this process that creates the activated sludge mass through decomposition. The term suspended growth describes the floating particles that are suspended within the wastewater where the microorganisms attach themselves and grow as the absorb oxygen. The microorganisms feed of the oxygen supplied to the wastewater, breaking the organics into two substances gas and protoplasm. The gas produced from the chemical reactions produce many different gas substances that are released into the atmosphere. The protoplasm or solid particles according to Davis (2010) have a specific gravity slightly heavier than that of water are removed from the treated liquid by gravity settling.

The NWWTP utilizes the activated sludge process through the oxidation ditch and through the final clarifier. The floor of the OD supports a blanket of sludge where the microorganisms grow and feed on the organic material and suspended solids (SS) heavy enough settle into the sludge. The microorganisms feed on the organics and solids releasing the treated gases back trough the wastewater to the atmosphere. To prevent sludge bulking the aerators at the NWWTP are used to resuspend the activated sludge from the bottom of the OD. This is achieved by the force from the aerators being directed down to the bottom of the OD by the baffles. This process lefts the sludge resuspending the solids allowing them to collided with the SS in the wastewater forming a larger particle which settles to the bottom of the OD back into sludge. The aeration process at the NWWTP when in operation transforms the sludge blanket is a moving mass allowing it to be continually recycled through the aeration process keeping it at as a completely mixed aerobic secondary treatment process. The activated sludge blanket is measured onsite by the operator conducting a settleability test. The test results allows the operates to set the amount of return sludge to be pumped from the clarifier to the OD inflow channel. The return sludge is used to increase the population levels of the microorganisms as they begin to die of in the OD.

5.3 What is Activated Sludge

Characteristics of wastewater sludge, including total solids and volatile solids contents, pH, nutrients, organic matter, pathogens, metals, organic chemicals, and hazardous pollutants (Federal Register 1993, USEPA 1995). A basic description of activated sludge is that it is made up of the organic matter that inflows into a wastewater treatment plant where it is mixed and aerated and held for a period of time to allow solids to settle thus forming the physical activated sludge. But there is so much more that contributes to, relies on and is happening within the activated sludge process. It is almost impossible to fully understand or monitor every reaction taken place within the activated sludge process but it can be broken down to physically and chemically processes involved. The activated sludge process can involve the physical process of flocculation and settleability, and the chemical processes of nitrification, denitrification and oxygenation and the life and death cycles of living bacteria that live in the wastewater.

The process design considerations for activated sludge are also vitally important. According to Lee and Lin (2007) the consideration that need to be included in the design phase are the hydraulic retention time (HRT) for reaction kinetics; wastewater characteristics; environmental conditions, such as temperature, pH, and alkalinity; and oxygen transfer. The design parameters and theory behind the activated sludge process are already well developed through more than 100 years of designs, redesigns, research and historical data. The different design approaches were proposed by researchers on the basis of the concepts of BOD5, mass balance, and microbial growth kinetics (McKinney 1962, Eckenfelder 1966, Jenkins and Garrison 1968, Eckenfelder and Ford 1970, Lawrence and McCarty 1970, Ramanathan and Gaudy 1971, Gaudy and Kincannon 1977, Schroeder 1977, Bidstrup and Grady 1988). The process of designing or modelling of the activated sludge process has become simpler and reliable with the development of computers and software and the ability of designers to build small scale field or laboratory pilot plants. Pilot plants have allowed the modelling of activated sludge and even wastewater treatment process to be carried out under and foreseeable consideration giving results that can be used to make reasonable assumption on how the process will perform.

5.4 Activated Sludge Processes

The physical process involved in the forming and maintaining the activated sludge to the required level of treatment the plant is aiming to achieve can be broken down to 1) Settleability, 2) Flocculation, 3) Aerobic, 4) Anoxic, and 5) Anaerobic.

Settleability

Settleability describes the ability, easy and time taken for particles heavier than that of the surrounding medium to settle to the base of the medium container or ground level. The purpose of settling or sedimentation is to remove settle-able organic and floatable solids. The density of the medium affects the ability of a particle to settle in particular the ability of particles to settle in water and wastewater. Particles that have a lighter density or weight than water will float and/or remain suspended within the water at varying levels because of the density changes in water due to pressure. Temperature, pH, alkalinity, turbidity, particle size, colour, conductivity and transmittance/absorption ability all have an effect on the settleability of particles in wastewater due to the affects they have on the density, specific gravity, specific weight, and chemical composition of the wastewater and solids. The type of wastewater also effects the settleability, where straight domestic wastewater would be easier to treat and thus settle than a combination of domestic, commercial and industrial. In particular industrial wastewater would need the enhancement of chemicals to create flocs heavier enough to settle depending on the constitute and chemical composition of the industrial wastewater. According to Spellman (2009), Davis and Cornwell (2008), and Eddy and Metcalf (2003) settleability of wastewater is expected to remove 90 to 95% settle-able solids, 40 to 60% total suspended solids, and 25 to 35% BOD. The most important process to control in the settleability of particles within wastewater is the mixing speed or particle velocity. By keeping the particle velocity low the settleability of the particle is increased.

The theory used for settleability is the same theory used for sedimentation as described in Chapter 3. Wastewater contains high concentration of particles and according to the theory of sedimentation described by Spellman (2009) the settling of wastewater falls in the category of Type III and Type IV sedimentation. Even tho the activated sludge settling process goes through the Type I and Type II sedimentation it is generally disregarded because the they are not the final sedimentation process.

Type III or Zone Sedimentation occurs when particles are at a high concentration level of greater than 1,000 mg/L. At concentration levels above 1,000mg/L according to Davis and Cornwell (2008) the particles tend to settle in a mass and a distinct clear zone and sludge zone or activated sludge are formed within the wastewater.

Type IV or Compressed Sedimentation occurs from the formation of the activated sludge mat. The formation of the activated sludge force or compresses the water from the sludge mat allowing the creation of a continuous almost homogenous sludge.

The settleability of the activated sludge and return sludge at the NWWTP are test on site by the operators. The operates take a sample of both sludge's and place the samples into a column cylinder where they measure the concentration of the particles. The measurement of the particle concentration is taken 5 times at 6 minute intervals. The value that is measured is in mille-Litres/second and represents the amount of concentrated sludge in 1 litre of the sample sludge utilizing the compression sedimentation. The final solution should consist of the two distinct regions, activated or compressed sludge at the bottom of the column and a clear liquid removed of particles at the top of the column. The tested results are used to determine if the sludge at the bottom of the clarifier needs to be wasted to the sludge lagoons and whether activated sludge in the oxidation ditch needs reseeding. Reseeding is the process of adding sludge to the activated sludge process that contains the bacteria used in biological wastewater treatment. The return sludge is pumped back into a system to repopulate or increase the population of useful bacteria that has died off.

Flocculation

The process of wastewater flocculation is to form aggregates or flocs from finely divided particles and from chemically destabilized particles (Metcalf and Eddy, 2003). Flocculation is the process of colliding particles to form larger particles called aggregate or floc, which are heavier than the liquid or gas that the particles are suspended. The formed heavier particles are removed from the wastewater by settling or filtration. The theory behind the process of flocculation was first observed by Smoluchowski in 1917 when he observed small suspended particles moving in random motion paths through water where the particles where colliding into each other. The theory was further expanded in 1921 when Langelier observed that the addition of mixing the water created turbulence that enhanced and increased the collision of particles with the increased velocity.

The process of flocculation in wastewater is generally seen after the mixing or agitation of the wastewater in the primary treatment, secondary treatment and advance treatment processes. The mixed solution produced is called mixed liquor suspended solids (MLSS) or mixed liquor volatile suspended solids (MLVSS) depending on the constitutes making the new substance. When the suspended particles are resistant to the combination via collision from the mixing or agitation process chemicals are added to destabilize the chemical composition of the particles. Chemical flocculation know as coagulation is a process used in primarily in second and advance treatment process. Coagulation is generally used in treatment processes that are treating industrial or commercial waste containing constitutes that cannot be broken down and remain suspended. Table 7 lists the applications for the different mixing and flocculation devices used in wastewater treatment.

Mixing Device	Typical mixing times, s	Applications/Remarks
Mixing and blending devices		
Static in-line mixers	<1	Used for chemicals requiring instantaneous mixing such as alum (Al^{3+}), ferric chloride (Fe^{3+}), cationic polymer, chlorine (Cl_2)
In-line mixers	<1	Used for chemicals requiring instantaneous mixing such as alum (Al3+), ferric chloride (Fe3+), cationic polymer, chlorine (Cl2)
High-speed induction mixers	<1	Used for chemicals requiring instantaneous mixing such as alum (Al3+), ferric chloride (Fe3+), cationic polymer, chlorine (Cl2)
Pressurized water jets	<1	Used in water-treatment practice and for reclaimed water application
Turbine and propeller mixers	2 – 20	Used in back mix reactors for the mixing of alum in sweep floc applications. Actual time depends on the configuration of the vessel in which mixing is taking place. Mixing of chemicals in solution feed tanks
Pumps		Chemicals to be mixed are introduced in the suction intake of the pump
Other hydraulic mixing devices	1 – 10	Hydraulic pumps, weirs, Parshall flumes, ect.
Flocculation devices		
Static mixers	600 – 1800	Used for flocculation of coagulated colloidal particles
Paddle mixers	600 – 1800	Used for flocculation of coagulated colloidal particles
Turbine mixers	600 – 1800	Used for flocculation of coagulated colloidal particles
Continuous mixing		
Mechanical aerators	Continuous	Used to provide oxygen and to maintain mixed liquor suspended solids in suspension in suspended-growth biological treatment processes
Pneumatic mixing	Continuous	Used to provide oxygen and to maintain mixed liquor suspended solids in suspension in suspended-growth biological treatment processes

Table 7: Applications for different mixing and flocculation devices

(Reproduced form Eddy and Metcalf, 2003, *Wastewater Engineering, Treatment and reuse*, McGraw-Hill)

The flocculation process of particles within the NWWTP process is carried out in the oxidation ditch and in the final clarifier. The OD uses mechanical aeration for the continuous mixing flocculation process and settling detention times of 12 to 24 hours. The clarifier uses gravity settling to remove the particles that were to light to settle in the OD in the 12 to 24 hour detention time and a skimmer to remove the particles or substance that floated on top of the wastewater. The sludge and waste removed from the clarifier is either pumped to the sludge lagoon and wasted or it is returned to the OD to support the activated sludge process and to allow further treatment of the sludge.

Aerobic

Aerobic digestion is a process of oxidation and decomposition of the organic material within the activated sludge by microorganisms with the presence of oxygen. The process of aerobic digestion is a chemical reaction that uses the oxygen molecules as the terminal electron acceptor. The final products of decomposition according to Davis (2010) are primarily CO2, water and new cell material (Shown in table 8) due to the oxygen being the terminal electron acceptor in the chemical reaction. Aerobic digestion is the most widely used method of sludge stabilization process because it offers a final stable product with a reduced mass and volume of the final activated sludge and waste sludge. There are many other advantages to using a aerobic digestion process. They include a reduction in pathogenic organisms found in wastewater that could harm to the public and environment. Aerobic aeration and digestion are less expensive to initially set and maintain compared to the anoxic process and very inexpensive than a anaerobic process due to lower capital cost.

Aerobic digestion is ideally suited for small treatment plants because of its eases of operation, ability to achieve quality treated effluent with minimal equipment and process steps and the production of a almost odourless end product that produces no potentially explosive gas such as methane. This also allows treatment plants to be built close to communities, which reduces the amount of sewer network to be installed and maintained. The disadvantages of aerobic digestion is the large operating cost. The aerobic digestion needs a continuous supply of oxygen and mixing to keep the process between the desired operating parameters. As stated earlier the aeration process in secondary wastewater treatment can consume up to 70% of the plants total power cost in the form of electric motors and compressors.

Temperature also plays a large part in aerobic digestion in particular in cold environments.

Representative end products		
Substrates	**Aerobic and Anoxic decomposition**	**Anaerobic decomposition**
Proteins and other organic nitrogen compounds	Amino acids Ammonia→ Nitrites →Nitrates Alcohols→CO2 + H20 Organic acids	Amino acids Ammonia Hydrogen sulfide Methane Carbon dioxide Alcohols Organic acids
Carbohydrates	Alcohols→CO2 + H20 Fatty Acids	Carbon dioxide Fatty acids Methane
Fats and related substances	Fatty acid + glycerol Alcohols→CO2 + H20 Lower fatty acids	Fatty acids + glycerol Carbon dioxide Alcohols Lower fatty acids Methane

Table 8: The breakdown of organics in the different aeration processes

(Reproduced from Davis & Cornwell, 2010, *Introduction to Environmental Engineering*, McGraw-Hill)

Anoxic

The anoxic decomposition is the process where some microorganisms within the wastewater use nitrate (NO_3^-) as the terminal electron acceptor. The anoxic decomposition process is brought about by the aerobic process not being supplied with enough oxygen. It staves the microorganisms that live on oxygen of food and allows microorganisms that can feed on nitrate to grow. The oxidation through this process is called denitrification. The end products of denitrification are nitrogen gas, carbon dioxide, water and new cell material (2008) (Shown in Table 8). Denitrification is a useful process in wastewater treatment where inflow wastewater has large concentration levels nitrogen or where the discharge environment requires the nitrogen to be removed before discharge.

The anoxic decomposition process is very easy process to setup and achieves good nitrogen removal results. the anoxic process can be designed into an existing wastewater treatment process by adjusting and controlling the level aeration delivered. Anoxic decomposition process can be achieved by stopping the aeration process and/or air supply for a extended period of time. This allows the microorganisms to consume the available oxygen. Once all the oxygen is consume the microorganisms will begin to feed on the nitrate reducing the level of nitrogen. The anoxic process is still mixed by low flow or velocities mixers that keep the sludge bed in motion and promoting flocculation.

Aeration tanks and oxidation ditches a ideal location to create anoxic treatment processes. Different treatment zones of anoxic and aerobic decomposition can be created within the channels. An complete aeration and denitrification treatment process can be creating that moves from anoxic to aerobic or some combination thereof. The final process or an additional process of aeration must be the last step in an anoxic treatment process. Aerating or re-aerating the effluent must be done before the its realised from the treatment process to the final clarifier in order to remove the unwanted nitrogen. Lumps of nitrogen rich sludge can formed in the final clarifier. The final clarifier adds no additional oxygen to the wastewater and the scraper and skimmer used in the clarifier tank move a very low speeds to avoid turbulence to allow further settling of particles. The nitrogen combines with the sludge and forms lumps of float nitrogen rich sludge that can move straight through the clarifier and into the other treatment plant processes.

There has been some success in old treatment plants that have added anoxic zones within the secondary treatment process. It has been achieved by developing a control and monitoring system that is capable of live monitoring of the secondary treatment process allowing them system to aerate and mixing when the DO level reaches a minimum value and turn off the aerators at a maximum DO level and still keep the mixing process operating at very low velocities.

The results for the DO levels recorded at the NWWTP shows that the secondary treatment process could be running as a anoxic process. For long periods the DO level at the NWWTP is below 1mg/L and as low as 0.1mg/L and referring back to the Hach operating parameters for the DO probe the actual reading could be 0mg/L.

Anaerobic

Anaerobic digestion is one of the oldest methods used to processes used to stabilization of wastewater. The process transforms organic solids in to sludge, in the absence of oxygen, to gaseous end products such as methane and carbon dioxide and to innocuous substances (Izrail S. Turovskiy and P. K. Mathai, 2006). The major difference with anaerobic digestion and anoxic digestion is that at no point in the treatment process is the sludge supplied with oxygen and the process is kept deficient of oxygen at all time. Anaerobic digestion has a large initial capital cost because of the equipment require to treat the wastewater. Large tanks or storage basins are required to store the wastewater for treatment which generally require a hydraulic detention time in excess of 10 days to achieve an effectively stabilized sludge. There is a trade off for a well designed anaerobic digestion process. The production of excess methane gas that is not used to maintain the temperature of the digestion process can be used as a energy source to power the mixers, aerators, or to generate electricity for the rest of the site.

The aeration process at the NWWTP maybe inconsistent but the process is an open ditch continuous flow aeration process. At any point whether the aerators are in contact with the wastewater or not some oxygen will be supplied to the effluent from the atmosphere and there is a continuous inflow of new influent daily. It would be impossible for the activated sludge process to turn into a anaerobic digestion process.

5.5 Chemical Reaction of Activated Sludge

The chemical reactions involved in the treatment of wastewater mainly occur during the aeration process and the forming of and the continual growth of the activate sludge. The processes that drive the chemical reactions in the development of activated sludge involve starving it of oxygen and limiting or controlling the level of oxygen concentration within the wastewater. The NWWTP plant being a continuous mixing aeration process the governing reaction would be from aerobic digestion.

The aerobic digestion process is the simplest reaction to understand with the oxidation of organic material and is illustrated below.

$$\text{organic matter} + O_2 \rightarrow \text{Bacteria} \rightarrow \text{cellular material} + CO_2 + H_2O$$

The cell mass or cell material of the microorganism is represented by the formula $C_5H_7O_2N$ and as the oxygen penetrates into the biomass the equation is illustrated by,

Destruction of the biomass:

$$C_5H_7O_2N + 5O_2 \rightarrow 4CO_2 + H_2O + NH_4HCO_3$$

The CO_2 is released to the environment and the H_2O is the treated effluent and the NH_4HCO_3 is ammonium hydrogen carbonate or ammonium bicarbonate. The ammonium bicarbonate uses the further addition of oxygen to produce ammonia nitrogen.

$$NH_4^+ + 2O_2 \rightarrow NO_3 + 2H^+ + H_2O$$

The end products are NO_3 is nitrate which later is turned into ammonia nitrogen which is released to the atmosphere along with the hydrogen and water. The overall equation for aerobic digestion with complete nitrification is.

$$C_5H_7O_2N + 7O_2 \rightarrow 5CO_2 + 3H_2O + HNO_3$$

This nitrification process is a easy process to control with the right monitoring system and controlling the oxygen. By keeping the DO level less than 1mg/L nitrification can occur and the process can still operate within the aerobic digestion reaction. The above chemical reaction should be the wastewater treatment process that the NWWTP under goes. The recorded DO results would indicate that the NWWTP would be undergoing some form of nitrification and denitrification due to the low DO results. This state would only be true if the DO tests carried out at the NWWTP where being carried out correctly and in the correct locations or multiply location within the OD.

When the supply of oxygen is turned off or stopped the nitrification process continues, using the remain oxygen until it is depleted. As the oxygen levels decrease the denitrification reaction begins and as discussed earlier it uses nitrogen as the electron acceptor and the reaction turns into a complete identification process and is illustrated below.

$$C_5H_7O_2N + 4NO_3^- + H_2O \rightarrow NH_4^+ + 5HCO_3- + 2NO_2$$

Where the final products are NH_4 ammonia gas, HCO_3 hydrogen carbonate which is a carbonic acid and NO_2 nitrogen dioxide. The combined of nitrification and denitrification reaction is illustrated below.

$$2C_5H_7O_2N + 11.5O_2 \rightarrow 10CO_2 + 7H_2O + N_2$$

This process allows for the removal of all the nitrogen as nitrogen gas and the carbon dioxide as gas to the atmosphere and the treated wastewater water remains in the ditch.

There are many other chemicals and chemical reactions that are taking place in the wastewater treatment process. The many purpose of secondary wastewater treatment is to remove the organics and chemicals that will be harmful to the environment such as nitrogen and phosphate.

5.6 Summary

Activated sludge is an important aspect to secondary wastewater treatment process that must be kept under controlled. If the activated sludge process falls outside the designed operating parameters the process could produce excessive amounts of undesirable such as nitrogen, which could result in the sludge having to wasted or treated with chemicals. A good monitoring system would prevent any issues with the activated sludge process and it would give the operators control over the process with the ability to change the process as required.

The NWWTP has little to no control of its activated sludge process with minimal testing. The NWWTP is design to operate as a continuous mixing aerobic process with DO level being kept between 1 to 3 mg/L. The tested results as stated earlier operate well outside these condition with no testing of the chemical composition of the activated sludge. The only test that is carried out is a settleability of the sludge which is done on site on a regular bases. This allows the operators to add sludge from the clarifier to help activated sludge process. Like many of the other process at the NWWTP there is no monitoring of the activated sludge process. The lack of monitoring means that the operators cannot change the aerations process for the activated sludge if it starts to move from the aerobic process to the anoxic process.

Chapter 6 Nanango Wastewater Treatment Plant

6.1 Introduction

This chapter gives an overview of the Nanango wastewater treatment process, including a brief history or the background of the town of Nanango as it relates to the its wastewater treatment process and development. The chapter will then turn its focus to the treatment plant flow process looking at the flow of the wastewater from when it enters and leaves the site. The last section will look at the equipment incorporated in the treatment plant for the main secondary treatment and the old treatment systems.

6.2 Background

Nanango is the 4th oldest town in Queensland with a local town centralised population of 2500 and another 2000 people live in the surrounding region. It was first settled in 1847 as a grazer's settlement and increased in population in the late 1800's when gold was found in the surrounding area. The area saw another population increases after World War 1 as the area became the terminus railhead for the Brisbane Valley. With little records in place it is believed that the current sewer network and the old treatment plant were constructed either between World War 1 and World War 2 or shortly after World War 2, while the new treatment process was installed in 1984 to handle the population increase due to the construction of the Tarong power station and coal mine. Figure 7 shows the whole plant flow process including the new and old system.

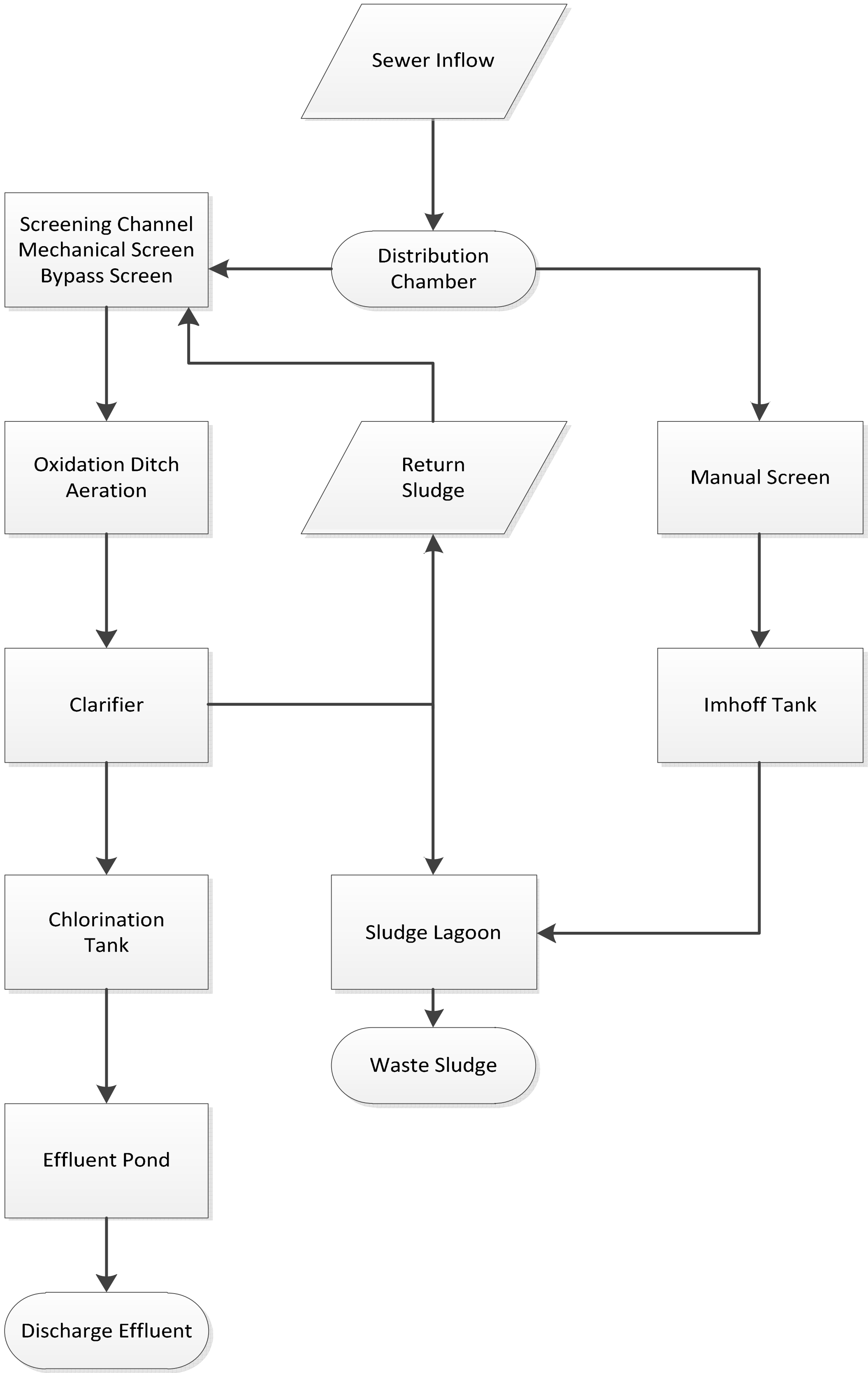

Figure 7: The Nanango wastewater treatment plant flow process.

The old treatment consisted of a manually cleaned screen, Imhoff tank, sludge lagoons and the holding pond. The current sewer network consists of the old ceramic pipes from the original laid network, along with the replaced concrete and the new polymer pipes sections used in repairs and town development. The sewer network does consist of one pump station that is used to pump sewerage from the south-east side of town which is lower than the centre of town. The sewer network only services the local town community of 2500 people. The majority of wastewater for Nanango is residential waste, the township has no major industry or commercial businesses and the major population concentration for the area occurs at the high and state schools.

6.3 Treatment Flow Process

The NWWTP is located out of town in an area that is geographically at a lower elevation than the main community and sewer network (Shown in Figure 8). The location of the treatment plant was chosen to help with the flow of the raw sewerage to the treatment plant which is delivered by a gravity feed sewer system. The treatment plant is a simple secondary wastewater treatment plant with no primary or advance treatment processes.

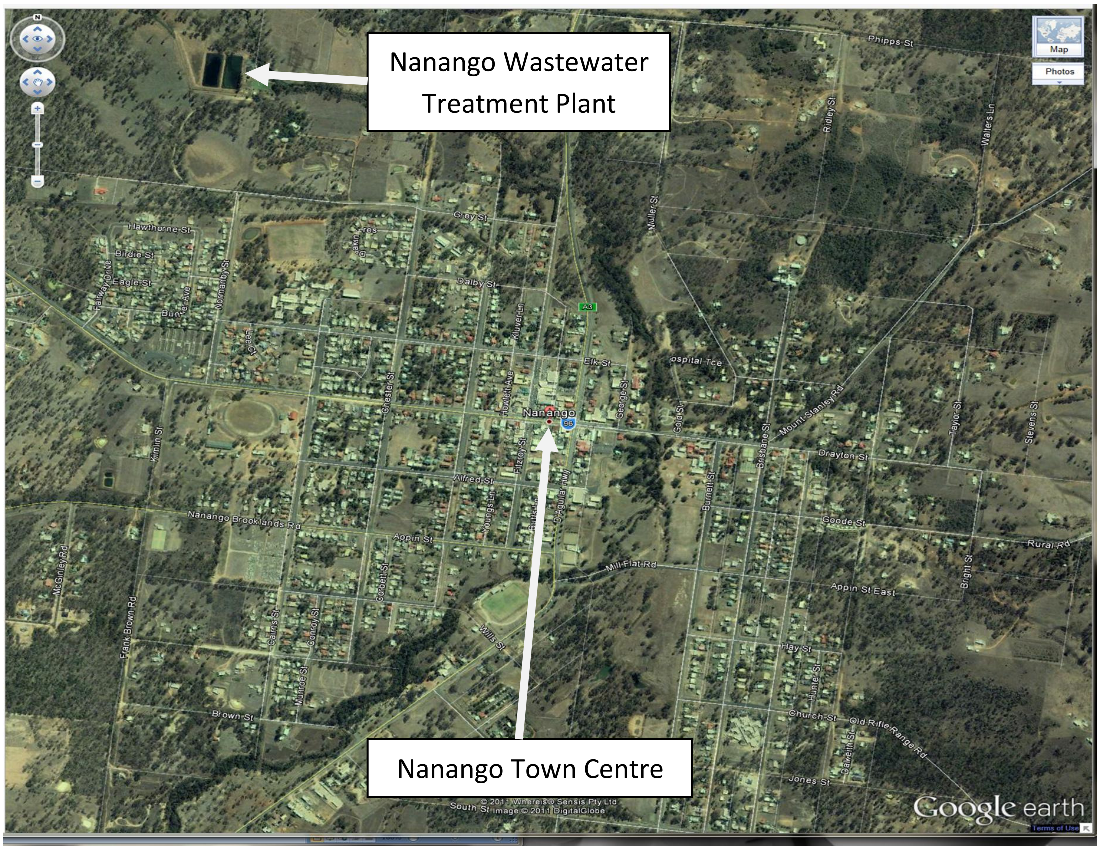

Figure 8: Location of the NWWTP compared to the centre of town, http://www.google.com/earth/index.html viewed 15/06/2011.

The current main treatment process utilises an oval shaped or race track extended aeration oxidation ditch for secondary wastewater treatment. The old treatment process, which is still in operation and used if the main process is out of service. (Figure 9 shows the aerial view of the layout of the NWWTP). The design of the process allows the raw sewage inflow to be divided between the old treatment system or the new secondary treatment process if the inflow is greater than the OD can handle. This is achieved by a distribution chamber located at the start of the plants inlet pipe network. After the distribution chamber the main or secondary treatment process begins with the raw sewerage passes through a screening channel used to remove solids. The inflow sewage is metered at the inlet structure of the OD via a flume flow meter. The screen channel is constructed from concrete and consists of the primary mechanical screen and a secondary manual screen, which is used to screen inflow sewage that is in excess of what the mechanical screen is design to handle. The manual screen is also used a bypass in case of break downs or maintenance is required on the mechanical screen. The screen channel is also used to mix the return sludge pumped from the clarifier with the inflow sewage. This is done to increase the population of microorganisms used in the biological treatment process and to allow suspended solids that did not settle in the OD first time around.

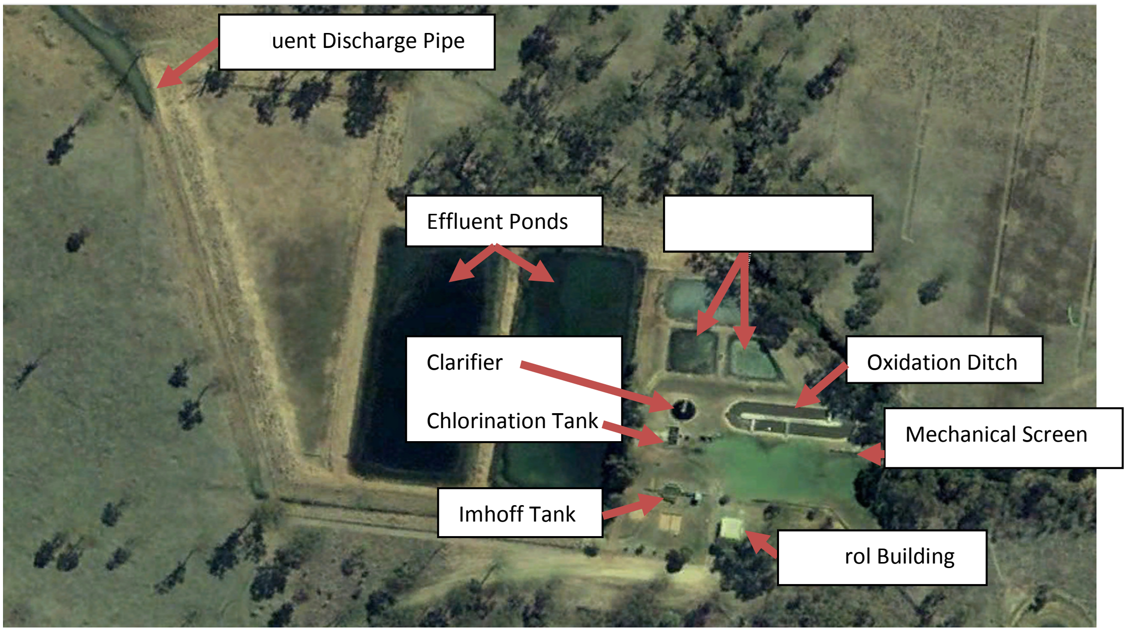

Figure 9: Aerial view of the Nanango wastewater treatment plant.

Once the influent has entered the ditch it is mixed and aerated by 4 horizontal mounted mechanical brush rotors. The oxidation ditch is main biological treatment process and due to its design the wastewater treatment is allowed to take place on a continuous basis. The detention time of the mixed liquor in the OD is 2 days. After 2 days the treated effluent passes from the OD into the clarifier. The flowrate between the OD and clarifier is controlled by a draw off weir located at the western end of the OD. The draw off weir is manually operated and along with the drawing off of effluent it's used to control the height of the OD. The clarifier allows the sludge and other particulates not settled in the OD to further settle. The clarified is a continuous process, where treated effluent passes from the clarifier over a v-notch weir into the chlorination tank while the settled sludge is draw off to the sludge lagoons and the floating particles, oils and greases are removed from the surface of the tank. The chlorination tank is used to disinfect the effluent, its designed to enhance the mixing of the chlorine gas water mix that is supplied from the chlorinator. Once the effluent has been disinfected it is pumped into a effluent lagoon and held before being pumped out to Sandy Creek. The waste sludge that was draw off form the clarifier is further stabilized and dewatered in the sludge lagoons before being removed from site. Figure 10 shows the main secondary treatment flow process at the NWWTP.

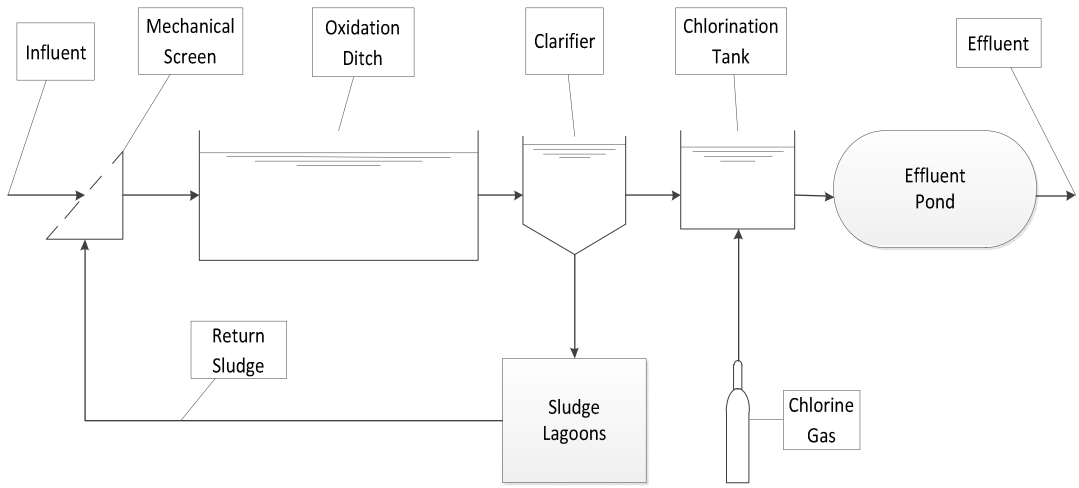

Figure 10: Main Secondary Wastewater treatment process

As mentioned in the earlier chapters the site also consists of the treatment process and equipment from the original plant which was installed in the 50s. The original equipment consists of a manual bar screen, and an Imhoff tank that was used as the secondary treatment process. The old treatment process and equipment is used as back to the new process, Figure 11 shows the whole site equipment layout and process flow. The flows lines in blues are the main secondary treatment process while the red flow lines are the back system to the Imhoff tank. The Chlorine and equipment used in the chlorination process is stored in a utility shed and delivered through a system of pipes to the chlorination tank.

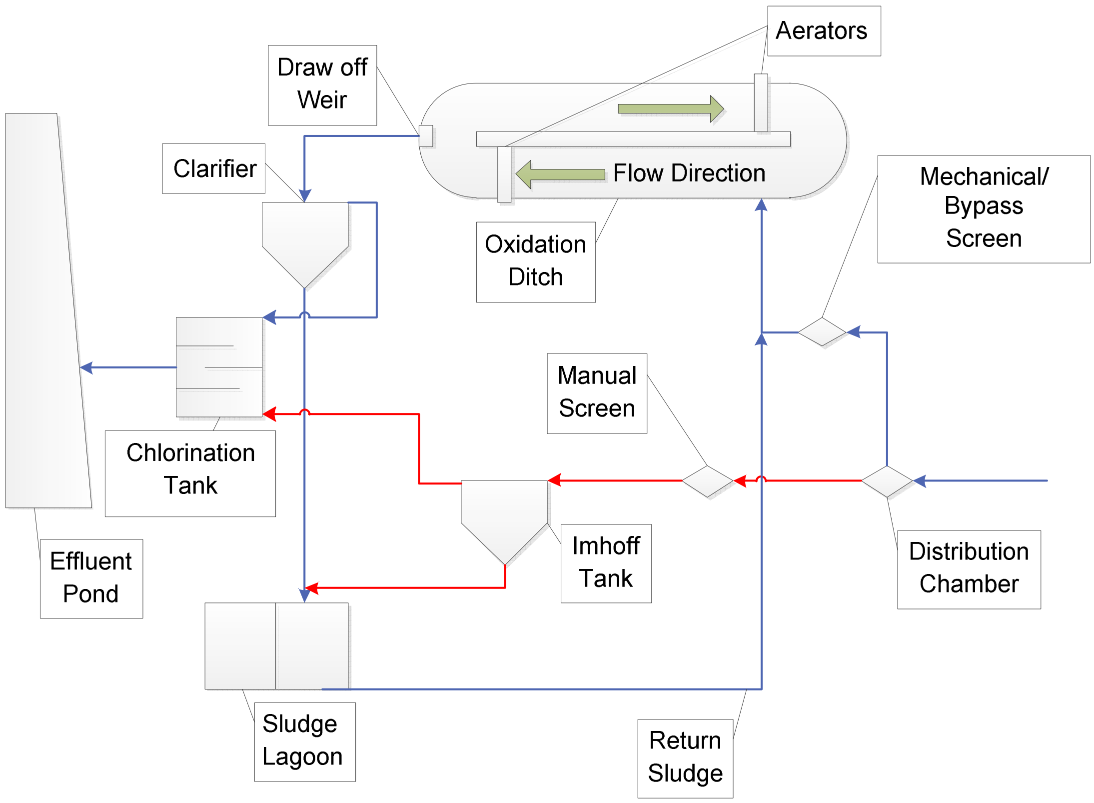

Figure 11: NWWTP whole plant equipment and process.

6.4 Nanango Wastewater Treatment Process Equipment

The current equipment in services at the NWWTP, ages from over 60 years old for the Imhoff tank to 20 plus years since the oxidation ditch, aerators and clarifier where installed or upgraded. This section explains is short detail the current equipment onsite at the NWWTP and where it fits into the treatment process. The oxidation ditch history, design and theory will be discussed in detail in the next chapter.

Oxidation Ditch

The oxidation ditch was discussed in chapter 3.

Aerators

The aerators and aeration process was discussed in chapter 4.

Imhoff Tank

The Imhoff tanks onsite is a standard design and consists of two compartments, an upper compartment which severs as a settling tank, while the lower compartment is used to stabilize the settled sludge anaerobically, which is removed from the tank by gravity. The tank is circular hopper shape that is sunk into the ground, constructed from concrete with a simple manual trash screen for filtering. The wastewater enters the tank through an inlet at the top of the tank and passes over a weir, which flows into a channel. The tank consists of atmospheric vents that travel down to the lower compartment suppling air to the settling sludge. Imhoff tanks have no mechanical equipment and have low maintenance requirements; they nonetheless have operational problems, including the periodic production of an odorous foam, excessive accumulation of scum in the gas vents, and production of odorous digested sludge (Linvil, 1980). Imhoff tanks have a long history of successful application for small plants and where maintenance and proper operation is problematic (Water Environment Federation, 2003). The settled sludge from the Imhoff tank at the Nanango plant is manually drawn with the use of gravity to a sludge holding pond which is located at a level below the draw off valve.

Screening

The influent wastewater that leaves the distributor for the oxidation ditch passes through a screening channel. The screening channel consists of a mechanically curved raked screen, a manually raked bypass screen, and an overflow bypass channel. The mechanical screen has spacing that is adjustable from 50mm to 100mm to remove large objects while still allowing wastewater to flow through the screen. The bypass screen is design to handle overflow from the main screen and to act as a backup to the mechanically screen in case of malfunction and or blockages.

Clarifier

The clarifier tank is used to settle the activated sludge from the mixed liquor that flows out of the oxidation ditch. The design of the clarifier tank at the Nanango plant is a circular basin concrete tank installed in the ground, figure ? is a photo of the clarifier tank. The mixed liquor enters the tank through an inlet pipe which carriers the influent to the centre of the tank. The influent is discharged into the centre of tank in a radial direction as up flow, it then deflects off a distribution box or feed well which cause it to change direction travel downwards. The clarifier uses gravity settling to remove solids in the influent. The clarifier has two functional zones, a clarification zone, where the process of gravity settling occurs, and a thickening zone where the settled solids are accumulated forming a dense layer of sludge (sludge blanket). The dense layer of sludge is continuously removed from the tank by the sludge scrapper arm, which use three V-notched channels at the bottom of the tank to concentrate the sludge for removal through the centre of the tank. The sludge is removed from the tank by a suction lift system that draws the concentrated sludge vertically up through pipes in the centre of the tank and out by a trough located under the access bridge.

The organic material that is to light to sink and settle with the sludge at the bottom of the tank and floats to the surface is removed from the tank with the use of a skimmer. The scum is removed from the surface of the tank, out through the centre in the trough with the sludge concentration. The activated sludge and scum from the trough is discharged into the sludge outlet pipe to the sludge pump station. The sludge pump station returns the sludge to either the screening channel for mixing with the new raw sewerage to be discharged to the oxidation ditch, or to the sludge lagoon. The pump station contains two pumps, a duty pump and standby pump that are operated by a float switch. The effluent removed of solids and scum passes over a V-notched weir around the outside of the tank and travels to the chlorination tank.

Draw off weir

The effluent draw off weir is located at the western end of the oxidation ditch and is a manually operated gate, which requires an operator to whine the gate down to draw effluent from the oxidation ditch to the clarifier.

Chlorination Tank/Process

The chlorination tank consists of a mixing chamber where the chlorine solution is added to wastewater effluent. The chlorine dosed effluent is detained in the chlorination contact tank to allow disinfection to occur. The effluent flows through a 90 degree V-notch weir, where the turbulence after the V-notch thoroughly mixes the chlorine solution with the effluent. The chlorinator is a vacuum operated, solution feed sonic device, which includes a vacuum regulator, flow meter, auto flow proportioning control valve and ejector. The effluent flow-rate is measured as it flows through the V-notch weir by an ultrasonic flow transmitter mounted above the V-notch weir that transmits to the chlorinator. The signal activates the control proportioning control valve which adjusts the chlorine gas flow rate to match the effluent flow into the chlorination tank. The control valve will automatically cut out when the low or zero flow conditions occur. The chlorination equipment includes an automatic change over system which consists of a motorized 3-way valve activated by a pressure switch.

The chlorination at the NWWTP has been design to enhance the mixing of the effluent and the chlorine before it is pumped the effluent lagoon. The chlorination tank has protruding wall sections that act like baffles to create turbulent mixing motion. The tank is constructed of concrete with three baffles as shown in figure?.

Sludge Lagoon

The sludge lagoons receive waste sludge for further stabilisation and dewatering. Two lagoons are located on site, one as the duty, the other as the standby lagoon. When the duty lagoon is full, waste sludge is fed to the standby lagoon. The floating material and scum from the sludge lagoon is discharged back to the oxidation ditch by pump to the screening channel while the settled waste sludge is removed for disposal. The lagoons are constructed from reinforced concrete and are of the same design as the oxidation ditch, where they are installed on top of a fine membrane material on a sand bed.

Effluent Pond

The effluent received from the chlorination process is stored in a large pond before it is discharged from the site into Sandy Creek. The effluent pond also know as a maturation pond allows the treated effluent to stabilize further. The NWWTP uses the effluent pond to transfer additional oxygen from the atmosphere or through a sprinkler system. The sprinklers are use to spray and circulate the treated effluent in and out off the pond use the atmospheric oxygen and the falling water theory to further aerate the effluent. The effluent is held in the pond for 30 to 45 days before being discharged to the environment. By law the discharged effluent has to meet stringent State and National environmental standards. It is worth noting that Sand Creek is normally dry bed sand creek that only follows with water during heavy extended periods of rainfall.

6.5 Summary

The current configuration of the NWWTP was built and designed to operate under the conditions that the township of Nanango was expecting to experience in the 80's and 90's. The foot print of the site is small and located far enough away from the local population so not to cause any harm or nuisance to the community. The original site planes shows that the council of the time had made prevision for further expansion if the expected population increase was larger than first predicted. The issue with the treatment plant is the age of the facility and the aging equipment employed in the treatment process. With the Worlds and in particular Australia focus on reducing energy usage and protecting the environment the current operating conditions at the NWWTP are becoming a concern.

When upgrading a wastewater treatment plant like the NWWTP the major or critical factors used to assess will be different than those used when designing a new plant. The option available for the plant upgrade will come from a different selection process and criteria. The upgrade process will need to look at issues such as;

- Can the current treatment process be improved or changed without installing any new equipment.
- If new equipment is required can the current site accommodate more or new equipment within the sites boundaries.
- Has the amount of inflow change since the process was design or is it expected to change in the future.
- If the new equipment is only a small part of the whole treatment process will the equipment work with the current process without changing the type and level of treatment currently being achieved.
- Will the upgrade change the quality or efficiency of the treatment process in a negative or positive manner.
- Does the upgraded process and/or equipment still allow the treated effluent to meet the discharge license issued to the site.
- Will the upgrade in any way change the discharge effluent chemical composition and/or concentration levels thus effecting the receiving body.
- Can the new process and/or equipment be integrated into the treatment plants control and monitoring system.
- Does the treatment plant need the addition of a control and monitoring system.

Chapter 7 Process Control and Monitoring

7.1 Introduction

This chapter will investigate the current control and monitoring process employed at the NWWTP along with the data recorded and its method of recording. It will pay particular attention to the measuring and recording of the dissolved oxygen levels in the OD. The focus will them turn to the control process with particular attention paid to the process used in the control of the aeration process. The last section will investigate possible alterative and improvements that could be made to the treatment control and monitoring process to improve the efficiency of the treatment process and reduce the power consumed.

7.2 Background

The monitoring and control processes employed in secondary wastewater treatment are as important if not more important than the type of equipment used. This statement becomes even more prevalent for aging wastewater treatment plants. If the monitoring and process controls are lacking, inadequate or non-existent than the equipment and process will operate and perform inefficiently and in turn use electricity with for no return in effluent treatment, which is currently being experienced at the NWWTP. In particular controlling the aeration in secondary wastewater treatment becomes doubly important. According to a study by Rieger, Alex, Gujer and Siegrist (2006) the air supply systems or aeration processes are a major factor in energy costs and can account for as much as 60% of the total energy consumed by the site.

The current process, design, and equipment used to treat the wastewater at the NTP are prone to poor performance. The equipment and process were last upgraded in 1984, when the oxidation ditch, aerators and clarifier were installed but no control or monitoring systems were installed at that time or in the years since. The treatment process instead relies heavily on operators to manually operate the equipment, control the system process, testing of the performance and efficiency of the equipment and process and the recording of tested samples and data.

Secondary wastewater treatment plants like that operated at Nanango, the aeration process is the most critical of all the processes incorporated into the treatment plant. The aeration process is used for two purposes, mixing the solids and particles within the wastewater to create larger particles for flocculation allowing for shorter settling and detention times. The other important function, which is critically important to the aeration process, supplying oxygen to the microorganisms. The microorganisms use the oxygen supplied through the aeration process as food in order to grow and intern break down the organics and harmful bacteria that live and populate raw sewage. The level of oxygen supplied to the wastewater, which goes hand in hand with the concentration levels of the dissolved oxygen within the wastewater in the oxidation ditch becomes the critical process to control at the NWWTP. The NWWTPs’ aeration process is controlled by three critical interlinked processes, (1) The level of DO within the OD, (2) The level or height of the wastewater within the oxidation ditch and (3) The immersion depth of the rotor brush aerator blades into the wastewater.

7.3 Dissolved Oxygen Monitoring

Dissolved oxygen is the term used to describe the amount of oxygen molecules within the wastewater and is measured in mg/L. According to Spellman (2009) secondary wastewater treatment DO levels need to be kept between 1 to 3 mg/L in order to promote and facilitate the growth of the microorganisms. The Victorian State Government Code of Practice (1997) recommends that the DO level be for a complete mixed aerobic process should be maintained between 1 to 4 mg/L. The level at which DO is controlled determines the type of aeration process that the plant is trying to achieve and this was discussed in Chapter 4.

The oxygen is used by the microorganisms as food and according to Eddy & Metcalf (2003) as the microorganisms grow they consume and break down the particulate biodegradable constituents into acceptable end products. If the concentration level of the DO within the secondary treatment process is allowed to drop below the 1mg/L level the microorganisms begin to die off and the wastewater will become septic or toxic unless the process is designed to operate in anoxic or anaerobic conditions. If the process is not designed to control these DO parameters the process will begin to build up of harmful bacteria and the wastewater will become untreatable and must be treated with chemicals or put back through the secondary treatment process to allow mixing with oxygenation. This issue will see an increase in the cost to run the treatment plant or through the purchase of chemicals. The correct DO control aeration process can improve the treatment plants operating cost and increase the efficiency of the whole process.

The dissolved oxygen levels at the NWWTP are tested in the oxidation ditch, clarifier, effluent pond, and effluent discharge are recorded by a portable hand held probe. Appendix D contains a table with the recorded DO results from the NWWTP for a period of 1 year. The results recorded are for the raw sewage inflow, the oxidation ditch, the clarifier tank, and the final effluent released to effluent lagoon. The results listed in Appendix D Table 15 are from 2010 for the months between January to July and December while the results for August to November are from year 2009. These were used because the results for August to November 2010 were not available and the other years were also missing some months. For the comparison made in this investigation the author tried to give the best representation of the NWWTP for a full year.

The DO results in Appendix D and Table 15 were obtained using a hand held probe manufactured by Hach, an international supplier of laboratory and field metering and censoring testing equipment. The data listed in Table 9 is taken from the Hach Company website for the specification for the HQ30d Portable pH, Conductivity, Dissolved Oxygen, ORP, and ISE Multi-Parameter Meter, which is the unit used at the NWWTP. The testing unit meets all the required American and international standards for the testing of wastewater. The way the unit is operated and calibrated makes it prone to incorrect readings. The unit if not calibrated at the required intervals or if the probe is not cleaned between samples or after sampling incorrect readings will be recorded. The fact that the unit can display readings of DO levels above 0.01mg/L this means the data collected from the NWWTPs' daily report sheets having DO test results which are 0.1, 0.2, 0.3 ect. means that the DO meter is not be used correctly or is being read incorrectly. The results shown in Appendix D Table 15 maybe incorrect as DO levels could actually will below what is actually being recorded in the wastewater. Highlighted in yellow in Table 9 is the exact wording taken from the Hach website on the units operational specification where it states that the DO resolution will only display readings of 0.01mg/L increments. Hachs' whole range of metering testing devices all have the same operating parameters for DO resolution.

DO range:	0.01 to 20 mg/L (0 to 200%)
DO resolution:	0.01 mg/L
Calibration intervals/alerts/reminder:	2 hours to 7 days
Conductivity range:	0.01 µS/cm to 400 µS/cm
Conductivity resolution:	0.01 µS/cm 2 digits µS/cm

Table 9: Data reproduced from http://www.hach.com/.

The actual process of testing the DO and operating the probe at the NWWTP is carried out by the site operators. They are responsible for the physical testing process and the recording of the results onto on the daily report sheet (Appendix B has an example of the daily report sheet). The DO testing or any testing along with the plants physical operation are carried out only when the operator attends site. The effluent discharge DO level, biological oxygen demand (BOD) and the suspended solids (SS) testing levels required by the Queensland Government environmental agency as part of the SBRCs' discharge licence are carried out by a third party.

The design of the whole NWWTP equipment, process and operation relies on the testing of the DO for the site run efficiently and/or only when required. The operators is not required to record the location, where the DO level was tested for any of the results. For the purpose of this report we are only interested in the DO results from the raw sewage inflow and the aeration tank or oxidation ditch and the location where the samples are taken.

The location where the OD's DO test is carried out is extremely important. Figure 12 shows the layout and the flow processes in, out and around the closed loop channel in the OD at the NWWTP. The DO levels in the NWWTP OD aeration process will not flow a standard pattern or profile. Variations in the DO levels would be experienced when the condition such as the inflow, dynamic loading, BOD levels and flow rates change. Variation in the DO levels would also be experienced if the aerators began turning a lower speeds delivering less oxygen, the immersion depth was to shallow and any sudden changes in the temperature to the wastewater. The shape of the OD also plays a factor in the OD levels where straight tanks would have a more defined DO profile compared to that of the OD with corners and slopped walls.

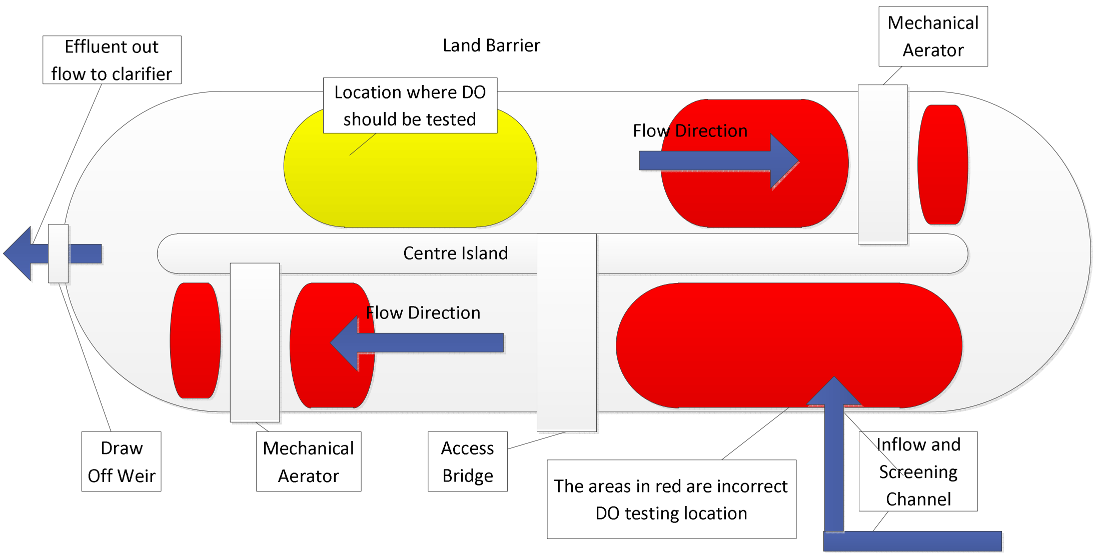

Figure 12: Layout of the NWWTP OD, showing flow direction and DO testing locations

In the NWWTP aeration process Incorrect readings will be recorded if, the DO test is carried out in any of the red marked areas. Results recorded close to the inflow will be similar to those recorded within the inflow screening channel or they will be a mixed result only slightly high then that recorded in the screening channel. This can be contributed to the already oxygenated effluent circulating the OD mixing with the inflow sewage. Because of the design of the aeration process and the possible variation in treatment condition there is no single location with the NWWTP OD aeration process where a DO sample could be taken that would represent the exact condition of the NWWTP process.

The DO results will also be incorrect if the samples are taken to close up or down stream of the aerators while in operation or shortly after operation. These incorrect results will be caused by the oxygen supplied and turbulence of the aerators during the mixing process. Figure 13 is an estimation of the profile of the DO concentration within the OD on the inflow side of the OD. The profile would show a distinct drop in the DO concentration level in the OD at the inflow region and a sudden increase at the aerators from the addition of oxygen.

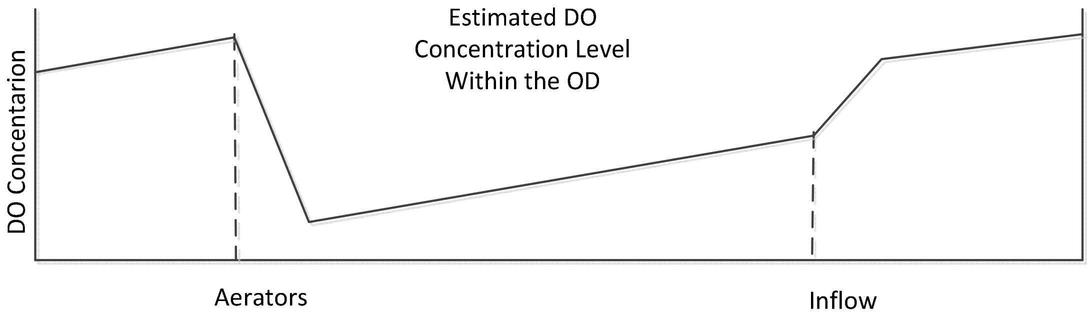

Figure 13: The estimate DO concentration levels on the inflow side of the NWWTP OD

The location within the OD where the operators should take DO samples, needs to be far enough away from the inflow channel and the aerators. The yellow area in Figure 12 shows the location where operators could take DO samples that would give a reasonable snapshot of the DO level. Figure 14 shows a profile of the estimated DO concentration level on the opposite side of the OD ditch to the inflow. The profile would be a smoother decline in the DO concentration until it reach the aerators and is re-aerated. But it would only be a reasonable results and not an actual representation of how the process is actually operating.

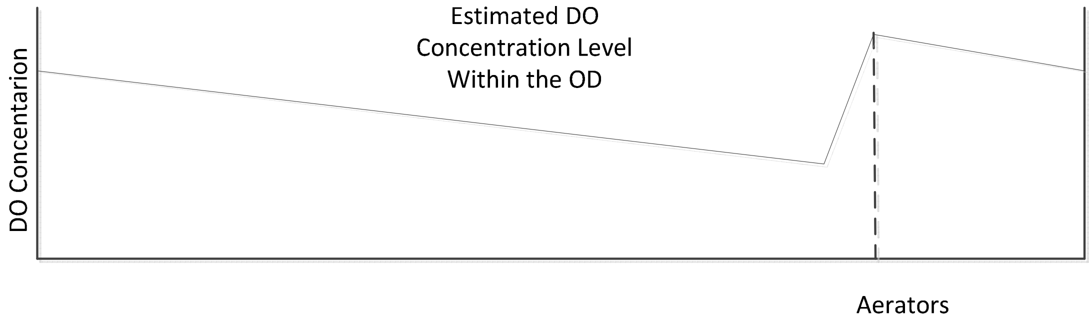

Figure 14: The estimate DO concentration level on the opposite side of the OD

The design and performance of the Nanango treatment plant is directly related to the DO samples taken by the operators. Operators set the aeration process which includes the mechanical aerators and the draw off weir from the DO sample results. The way in which the NWWTP process is designed incorrect DO readings will lead to a flow on effect of poor performance throughout the process and excessive amounts of power being consumed with little to no effect on the effluent quality.

7.4 Wastewater Height

The height at which the wastewater is controlled in the OD is by the draw off weir located at the end of the ditch. The design and operation of the OD and the equipment used for the aeration process in the OD at the NWWTP also relies on the draw off weir. Along with controlling the flow of effluent to the clarifier and the height, the draw off weir also controls the immersion depth of the aerator blades into the wastewater via the height of the waste water.

The draw off weir is a manually operated gate that requires the site operator to whined the gate to the required draw off height. The point or height at which the operators set the draw off weir is via a visual inspection of the height of the wastewater while they are on site. The operators also base the height of the weir gate from the flow rate of the inflow sewage which is measured by a flume flow meter on the inflow screening channel. The OD has no water level monitoring system or sensors and no control system for the draw off weir. The immersion depth of the aerators is critical to the effluent treatment process and according to the site operating manual the aerators should be operating at a maximum immersion depth of 200mm. The design of the aerators and the OD allows for a maximum wastewater height in the OD of 1.7 meters anything above this would submerge the motor and gear boxes.

The draw off weir also acts as a safety over flow for the OD, which is used to protect the motor and gear boxes and to stop the un-treated effluent from contaminating the environment. If the water levels gets above the safety level of the weir gate untreated effluent and solids could pass over the weir and into the clarifier. High OD water or those above the recommended for the aerators maximum immersion levels would place extra stress and strain on to the motor and gear boxes operating the aerators. This could lead to over loads on the motors and gear boxes causing motors to burning out, the excessive wearing on bearings and drive trains, increased maintenance cost and down time. Low OD water levels or water levels that do allow for aerator immerse in to the wastewater could lead to the same problems as high OD water levels. The low OD water levels could also contribute to extra stresses and strains due to no loads being place on the aerators allow them to vibrate and become unbalanced. The high OD water levels would contribute to increase in the energy consumption due to the extra force applied to the aerators while low DO levels will see a waste in energy for no return in treated effluent.

There are combined system available that would monitor and record the height of the wastewater and also measure the flow of the wastewater. Height and flow meter measuring sensors can be install on the all the major and critical operations at the NWWTP, which can be integrated into a main controlling and monitoring system.

7.5 Case Studies and Research Papers

There are research papers and case studies available that high light the potential savings and treatment efficiency increases achieved by incorporating control systems into old treatment processes. Presented below are 3 examples of adopting new control systems and monitoring process into a old treatment plant and the improvements experienced.

1. *The original design for the 2000 UC Davis Wastewater Treatment Plant (WWTP) relied on manual aeration control to maintain desirable dissolved oxygen (DO) levels in the oxidation ditch. Given the large daily variation in flow and wastewater strength, WWTP operators found it difficult to maintain stable DO levels. As a result, operators typically erred by providing too much oxygen, and the ditch was often found to be in an over-aerated state. Thus, the original control strategy wasted energy and promoted unstable biological conditions.*

   In January 2004, UC Davis installed a new system for continuously measuring DO in the oxidation ditch and automatically controlling aeration. The project scope included installing a "floating ball-type" DO monitor, adding variable speed drives (VFDs) on two aerator motors, and programming a PLC to automatically vary aeration in response to measured DO levels in the oxidation ditch.

   The process control changes necessary to automate oxidation ditch aeration at the UC Davis WWTP were relatively easy to implement and our data indicates that the project has significantly reduced energy use while maintaining or improving effluent water quality. After twelve months of operation, our principal conclusions are as follows:

   • The availability of a debris-free, low-maintenance, in-line DO meter is an important innovation that makes automatic DO loop control operationally practical for activated sludge treatment systems. The tested DO monitoring system has proven to be extremely reliable with very little maintenance required. The automated control system has consistently maintained set-point DO levels in the oxidation ditch without discernable drift or error.

   • The use of VFDs for oxidation ditch aeration in conjunction with DO feedback-loop control has reduced WWTP electrical consumption by an average of 23% or 755 kilowatt-hours per million gallons (kWh/Mg) (Figure

6). The project was found to have a 1.2 year payback at the prevailing municipal electrical rate of $0.09/kWh.

• Beyond energy efficiency, the ability to maintain DO at prescribed levels in the oxidation ditch has afforded operators a higher degree of biological process control. Effluent quality has improved as a result. The sludge volume index (SVI) increased from an average of 84 to 99. Ammonia as nitrogen has consistently remained below 0.5 mg/L after implementation.

• The revised system was designed to consistently maintain DO at fixed levels with the goal of maintaining a stable biological treatment process. However, other control strategies that vary DO levels over time are also possible. Use of variable DO control strategies might allow for a further reduction in energy consumption or enhanced biological treatment. These concepts are recommended for future study.

Given these positive results, operators of existing activated sludge WWTPs with manual aeration and designers of new WWTPs should consider implementing similar process control strategies.

(David L. Phillips, P.E.*, and Michael M. Fan, P.E.)

2. *The City of Bartlett, TN, WWTP is a 1.0mgd (average daily flow) secondary facility utilizing two mechanically aerated oxidation ditches to provide secondary treatment. Each of the aeration basins is equipped with three rotor aerators. Prior to implementing their aeration system modification ECM project, each basin was operated using one (each) aeration rotor running continuously and a second rotor activated daily (and run at full speed) during periods of peak flow.*

   Under the Demonstration of Energy Efficiency Development Research Program funded by the Tennessee Valley Authority (TVA) and the American Public Power Association (APPA), the City of Bartlett Wastewater Division implemented optical DO sensor technology integrated with VFD speed control of the oxidation ditch rotor aerator. The objective of the TVA/APPA research/demonstration project was to advance the use of optical DO sensor *technology integrated with VFD motor speed control to achieve energy savings at small to medium sized wastewater treatment facilities (i.e., < 10 MGD) within the TVA service area.*

Under the demonstration program, the DO control set point was established in each basin at 1.2 mg/l, and the rotor speed controlled based on the DO readings in the oxidation ditches, relative to set point. During the demonstration program, one rotor in each basin reached full speed for only 20 to 30 minutes each day during the peak flow period. The second rotor was not, and has not ever been, required to maintain the oxidation ditch DO set point concentration.

The optical DO sensor technology and aeration rotor VFD controls were installed and commissioned for $13,500 ($2007). Following implementation of the aeration system modifications, first year (2008) energy consumption was reduced by nearly 72,000 kWh (13 % reduction) and peak demand was reduced by 51 kW (a 39 % reduction). The resulting energy cost savings was $9,176/year (a 22 % savings). The project resulted in a payback of 1.5 years.

(EPA, USA, Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities)

3. *The Oxnard, CA Wastewater Treatment Plant serves a population of approximately 200,000 people and treats an average daily flow of 22.4 mgd. The trickling filter-activated sludge treatment facility uses Turblex blowers and associated proprietary pressure based control software to automate the activated sludge aeration process. To address aeration basin foaming and clarifier sludge bulking problems, the facility implemented activated sludge process optimization and automation utilizing the following integrated components:*

- *Replaced the aeration blowers' pressure based control software with DOmaster™ control software. DOmaster™ (an Ekster and Associates, Inc. proprietary biological process control software) utilizes biological treatment* *process modelling based algorithms and process data mining algorithms to effect DO control.*

- *Installed InsiteIG optical DO sensor technology replacing outdated membrane probes.*
- *Installed two total suspended solids (TSS) monitors, one in the mixed liquor channel and one in the Return Activated Sludge wet well.*
- *Installed SRTmaster™, Ekster and Associates, Inc. proprietary software providing real time control of the activated sludge process SRT. The software utilizes a biological process modelling based control algorithm which maintains minimum variability of wasted solids (over the course of a day) resulting in significant improvements in solids settling/thickening.*
- *Installed OPTImaster™, Ekster and Associates, Inc. proprietary software which optimizes the process control set points for SRT and DO in each of the facility's aeration basins.*

The effect of these modifications was improved biological process stability and discharge permit compliance and reduced Sludge Volume Index [SVI] (20% for average SVI and 50% for maximum SVI). Since the implementation of this ECM, foaming in the aeration basin has not occurred. In addition to improving the stability of the biological treatment process, improved solids settling/thickening and elimination of foaming, blower energy consumption was reduced by 306,600kWh/yr (a 20 % reduction). This reduction in energy consumption represented a nearly $27,000/year savings in electrical energy costs. Polymer dosage for thickening was reduced as a result of the improved settleability of the biological solids, resulting in a reduction in chemical costs of $7,500/year. Additionally, the improved automation of the aeration process reduced labour costs by $18,500/year.

The total project implementation cost was approximately $135,000. The payback, considering only energy savings was approximately 5 years. Including the chemical cost savings and labour savings in the payback analysis reduces the payback period to approximately 2.5 years.

(EPA, USA, Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities)

The United States Environmental Protection Agency has extensive information, data, research and case studies pertaining to wastewater treatment plants across the entire United States. The EPA has developed strategies and guides for the state and local governments as well as private treatment operators to follow, to reduce energy consumptions and increase efficiency. One of the main focuses of the EPSs' energy management strategies is to introduce new equipment to old treatment process in particular automated control and monitoring processes. The case studies above show that the implementation of the program is show excellent results in reducing energy usage. The majority of the research papers and case studies involving controlling system upgrades also involved the installation of either new aerators or blowers. The old motors were replaced with new variable frequency drive (VFD) motors that with the addition of the controlling system and probes are able to operate at different speeds. Without the probes or controlling system the motors would need a timing circuit or sequence circuit. The probes and controlling systems in the research papers and case studies allowed the VFD motors to operate efficiently and only when required which lead to reduction in power consumptions and ultimately monitory savings.

7.6 Control and Monitoring Systems

There are numerous methods for controlling and monitoring wastewater treatment plants equipment and processes. In the past and what is the current process use at the NWWTP monitoring and control was carried out by site operators using visual inspection, timing circuits, historical data, flow meters, and experienced skilled operators how had operated the site in past and knew how the system worked and reacted under different conditions.

The old methods of controlling and monitoring wastewater treatment plants are no longer viable for today's environment. With strict environmental laws being introduced in the last 20 years, governing the quality of effluent discharged to the receiving body or for reuse, controlling the treatment process became important. Now with the focus on the carbon emissions and reducing energy usage and alternative energy sources controlling the treatment process has become paramount. Treatment plant operators are now trying to increase effluent quality while focusing on reducing the energy consumption, controlling the process and replacing the old equipment with new more energy efficient equipment that can be controlled through computer programs.

Treatment plant operators have been helped in the last decade with their efforts to control their treatment plants processes with the advent of computer technology, PLC technology, software and improved sensor technology. Computers and computer hardware have become inexpensive and very powerful in the past two decades. The increase in the capabilities of computers has seen them used to calculate large algorithms to solve complex problems, used as control and monitoring systems for process control, live real time data processors and as data storage, trending and reporting systems. Integrating sensors and PLCs into the computer system and organising the system into a computer software program that is capable of reading, calculating, organising, and plotting the data into useful information plant operators would be able to follow the treatment process in real time and adjust and correct the process as needed. The computer software available today is capable of being used to control the treatment process remotely. Operators with the use of the software interface and programmed PLC units could make adjustment to treatment process on the go without being on site or without leaving the office.

There are many different types of off the shelf propriety software that is capable of being programmed to operate a wastewater treatment plant in a full automated mode. Citech SCADA software is one such program that allows the user to control, monitor and record what is happening in the system. The SCADA software is designed so that users are able to input all the required equipment and sensor settings for each individual site without the need of an expert computer programmer. The software is generally not designed to operate specific equipment or processes but to allow the user to define what is going to be control and monitored. It is designed to operate through sequence command modules. The software utilizes Programmable Logical Controls (PLC) to connect to the power connections and data ports to relay the data back to the computer. The software then processes the data relays back to the PLC a control sequence of open and close commands that controls the equipment. SCADA is one of the most powerful software and PLC control systems available. It not only allows the computer and software to control and monitor the system it is capable of storing historical data and creating user defined reports and trending and real time data that can be accessed by user onsite or remotely through a web interface console. SCADA can also be combined to a radio or telemetric systems to allow the software to call out to phones, mobile phones, wireless devices, emails and radios error codes and messages that allows the operators to know what is happening including break downs and process that are not running efficiently.

Case Study

Wide Bay Water Corporation

It was against this backdrop that Wide Bay Water Corporation (WBWC), the first local government-owned corporation in Queensland, was tasked to build a new state-of-the-art wastewater treatment plant (WWTP). The AU$33 million project was undertaken to provide the additional wastewater treatment capacity required to keep pace with the area's rapid population growth.

The Challenge

In planning its seventh WWTP, to be its largest and most complex to date, Wide Bay Water Corporation set out to build a facility with a capacity equivalent to the water use of 10,000 homes, or 4.8 million litres per day. The facility, situated beside an 800 ML effluent lagoon at Nikenbah, also needed to be able to expand its capacity nearly three-fold in line with population growth to 14.4 ML/d. Using sophisticated *new filtration technologies, the wastewater would be treated to a standard above EPA levels with the aim of recycling 90% of the treated wastewater from the plant. The quality of the treated water would be so high that it could be used as a supplementary water source for irrigation or potable water substitution in future drought situations.*

The Solution

WBWC selected Schneider Electric as its single provider for a number of key reasons:

• Schneider Electric offered proven technology with a solid local track record.

• Schneider Electric was able to provide the complete process automation solution PlantStruxure - from a single, strong brand.

• Schneider Electric's equipment shared a common look and feel for ease of use.

• Schneider Electric's spare parts were stocked by local wholesalers, reducing the need to stockpile them.

Benefits

• Reduced energy consumption o The use of variable speed drives to control the majority of the motors greatly reduced energy consumption as the pumps and mixers can operate at their duty points. Energy consumption has been reduced by approximately 12.5% compared to a similarly sized plant.

• Reduced operating costs o The high level of automation at the plant and its robustness means that only one operator is needed on site. A similar sized plant operated by WBWC requires both an operator and an assistant. The reduced manpower requirement means a savings of $50,000 per year. o Fault detection time is greatly reduced as the entire plant can be interrogated from the control room thanks to the SCADA system.

(Citech, *www.schneider-electric.com,* 2010)

PLC

PLC have also come a long way in the last 20 years in particular with the introduction and development of Ethernet and USB connections. These connections have allowed for fast data transfer rates of up to 1000MB/s for Ethernet and 5GB/s for USB. The faster Ethernet transfer rate has allow the real time commanded and control protocols between the computer, PLC and equipment to become also most instant and much more reliable than the old pin in and pin out connections. Ethernet has also allow the transfer of muck more data than could be achieved previously. The develop of USB has allowed for easy of programming of PLC through the introduction of easier to use and program PLC that use a GUI interfaces. Combining the computer, software and PLC into one system has become an easier process than experienced in the past and the addition of sensors has turned it into a complete control system.

7.7 Sensors

A good control and monitoring system for wastewater treatment will need to be able to detect what is happening within the wastewater during the treatment process. The evolution of sensors and sensor technology has becomes extremely important in the process industry. Sensors allows operators to monitor system processes live and in real time, allowing them to immediately adjust the process when it moves outside the required settings.

Of particular concern to wastewater treatment process is to control the oxygen, pH, nitrogen, phosphate and ammonia concentration levels within wastewater. The concentration levels of these substances can all related to the to the BOD and COD levels within the wastewater. Sensors to monitor these substances are readily available in particular sensors that can detect the exact levels of oxygen and pH in wastewater are widely available and very inexpensive. There are no dedicated sensors to monitor nitrogen, phosphate and ammonia levels within wastewater.

Sensors that can detect changes in nitrogen, phosphate and ammonia levels do not detect the exact substance instead they detect the changes in Ion levels.

The sensors are setup to detect changes in a specific references cell or cells Ion concentrations levels. Ion-selective electrodes (ISE) consist of an ion-specific half-cell and a reference half-cell (Dr. Axel W. Bier, 2009). The reference cell is used to calibrate the sensor for the specific substance via a reference solution. In order to characterize ISE behaviour, it is necessary to prepare standard solutions of the specific ion in terms of logarithmic concentration values, (e.g. 0.01 / 0.1 / 1.0 / 10 / 100 / 1000 mg/L standards) (Dr. Axel W. Bier, 2009). The downfall to this process is that the ISE sensors require regular re-calibration for the specific Ions or if the level of concentration to be tested is changed. Temperature also plays a large part in testing of the Ion concentration levels with the sensors needing to be re-calibrated for different seasons. The theory and process of the chemical and substance process will be explained in Chapter 5.

Temperature plays a large part in the wastewater treatment process. Temperature sensors placed on critical areas of the wastewater treatment process, in particular the aeration process will allow for a more efficient treatment process and a better quality effluent. Temperature sensors could be used to judge when the other sensors should be removed for re-calibration in the change of seasons. Temperature sensor readings would also allow the process control system to make critical adjustments to the aeration process during extended periods of harmer or cooler periods that are normally not experienced.

7.8 Summary

Through this research, it is clear that before any new equipment is to be purchased for the NWWTP the plant owner needs to gain control over the physical and chemical processes employed at the treatment plant. The owners need to gain an understand what is happening in the current treatment process and have a clear vision of what they want to achieve out of the process. This would be achieve if the owner adding a control system that would allow the process to run as needed and in a correct and timely fashion. Adding monitoring devices would allow the control system and the operators of the NWWTP to gain a much better understanding of what is happening at each critical or even non-critical points within the plants treatment cycle. Case studies have shown and proved that a control and monitoring system can significantly reduce the power being used by a treatment plant and improve the quality of the treated effluent being discharged without replacing equipment.

Chapter 8 Discussion

8.1 Introduction

This chapter discusses the alternative treatment methods and improvements that could be made to the NWWTP. The chapter will discuss the alternative aeration processes available that could be integrated into the NWWTP. It will also make recommendation on methods that would improve the efficiency of the plant as well as the control over the treatment process.

8.2 Research and Project Limitations

The information and data presented and used in this project was limited to the data that was supplied by the SBRC Water and Wastewater Department. Some of the limitations of this project were, a lack of process and data information, power consumption details and costing, the site discharge license and the results for the offsite BOD, COD and DO tests. The SBRC was not able to supply this information due to confidential nature and/or not having the information to supply.

The available literature on wastewater treatment and in particular secondary or biological wastewater treatment is very extensive and well recorded. This made the back study and research into what might be happening within the NWWTP aeration process to cause the DO results that were recorded. The large amount of literature and case studies used within the research made it ? to make assumption about the problems uncounted at the NWWTP even with the lack of suppled information.

8.3 Alternative Aerators

The research has shown that has been vast improvement in the design and operation of aeration equipment since the NWWTP was built in 1984. The current aerators employed are a limited system that are not controlled by the demand of oxygen or mixing the treatment process requires. Instead the aerators are controlled by the level of wastewater or the height of the wastewater in the OD compared to the aerators.

Improving the Current Aerator

Before consider new aerators it should be investigate if the current aerators are capable of being up graded or modified to improve the performance. The treatment plant owners should investigate whether it is possible to re-engineer the aerators motor mounts to make it possible to raise and lower the units with the level of the wastewater. Also If the motors are a 3 phase unit then a variable frequency drive also known as a variable speed drive could be installed onto the motors. The VFD would allow the motors to operate at different speeds by changing the frequency delivered to the motor. This can reduces the cost to operate the motors by up to %20. Table 10 is reproduced from the Queensland's Governments Eco-efficiency fact sheets shows that by install a VSD onto a 5.5kW motor 20% power saving was achieved for a 1 year payback.

	5.5kW motor with no VSD	5.5kW motor with VSD
Annual energy use	44,000 kWh	35,200 kWh
Annual energy cost	$6,655	$5,324
Annual energy savings		$1,331
Cost of VSD		$1,295
Payback		1 year

Table 10: Assumption: 8,000 operating hours per year, 20% reduction in energy consumption due to VSD, electricity cost 15.125c/KWh

(Reproduced for the Queensland Governments Eco-efficiency Project Office.)

Replacing the Current Aerators

The selection process for replacement aerators at the NWWTP would need to account for a number of condition factors that cannot be changed the most important being the oxidation ditch. The OD is a fixed concrete structure that with a set depth and width. Therefore the aerators would need to fit within these constraints while still delivering the required amount of oxygen. If the section criteria was given and a set of selection parameter to replace the aerators was to be based off the maximum amount of oxygen the current aerators are delivering. Than the parameters of the selection criteria could be reduce to three simple conditions. There should be a wider range of selection parameters that should be considered. But the lack of information and recorded data about the NWWTP would limits the selection criteria to the three basic selection below.

1. The aerators cannot be any wider than a maximum of 6m
2. The aerators must be able to operate in shallow depth of 1.8 to 1.2m
3. The aerators must be capable of deliver 435Kg of O_2 in 1 day

On this basic selection criteria above there are a number of possible alternative aerators that could be use to replace the current aerators and a number that can be ruled out due to the design of the NWWTP and the treatment process. The aerators that can be ruled out as replacement units are the diffused aerators. This would be because the ditch is not deep enough for the diffused aeration process to work correctly. Diffused aerators require a minimum depth of 4 meters to achieve correct aeration. There are several mechanical aerator such as the Aeration Industries, AIRE-O_2 TRITON floating aerator, which requires that the minimum depth of the wastewater be 1.8m.

There are many possible alternative aerators available that are capable of achieving the required level of aeration at the NWWTP. Even though the aerators are capable of delivering the required level of oxygen their operational function may not be suited to the OD, complete aeration process as operated at the NTP. Listed below are three possible alternative aerators that operate using different equipment and operating parameters.

S&N Airoflo Floating Brush Rotor Aerator

The S&N Airoflo inc. make a floating brush rotor scoop aerator unit that is designed as a single unit with the motor and rotor mounted on the same floating platform shown in Figure 15. They also have a range of motors varying in horsepower from 5 to 20HP, rotor lengths from 1.2 to 4.2m and rotor diameters of 90cm to 105cm. The units also have the flexibility on the method of installation. They are connected to bridges, a dedicated access platform, or by anchor cables. The units can also be moved around the ditch if the process requires. The brush rotors have been tested and are capable of delivering 3.0lb/HP - hr in clean water and have been field test at 2.3lb/HP - hr at 65 rpm. Using the values provided by S&N Airoflo and adjusting pounds to kilograms table 11 list the expect oxygen deliver levels for the four HP motor configuration.

Using the figures for the brush rotors and comparing them to the current rotors in operation two 10 HP Airoflo brush rotors could be used to replace the current aerators. They would be capable of delivering 572 kg-O_2 in 1 day in the same amount of time as the current aerators. There would also be a reduction in power consumed due to two motors running at 7.46 kw compared to four motors running at 5.5 kw. The units also have the advantage of not be fixed, which allows them to be removed from the ditch for simple routine maintenance. The floating platform would see the aerators in correct contact with the wastewater at all times because of the ability of the platform to move up and down with the height of the wastewater.

kW	HP	Clean Water 3lb/HP -hr	Field Test 2.3lb/HP -hr	Clean Water 1.36kg/HP - hr	Field Test 1.04kh/HP - hr
Motor	Motor	lb-O_2 /hr	lb-O_2/hr	kg-O_2/hr	kh-O_2/hr
3.73	5	15	11.5	6.8	5.2
7.46	10	30	23	13.6	10.4
11.18	15	45	34.5	20.4	15.5
14.91	20	60	46	27.2	20.8

Table 11: Oxygen delivered by the S&N Airoflo brush rotor for different motor size (Reproduced from Airoflo Industries, www.airoflo.com)

Figure 15: S&N Airoflo floating brush rotor

DBS Manufacturing Floating and Bridge Mounted Aerators

DBS Manufacturing produce two low-speed surface aerators that are capable of achieving the required aeration needed at the NWWTP. The NSA series aerator shown in Figure 16 is a floating aerator that is attached via anchor cable to stop the unit from moving. The motor is mounted onto of the floating platform and like the S&N aerator is easy to maintain by removing the unit from the ditch. It is manufactured with a number of configuration with different sizes of floating platforms, motors and mixers. Table 12 is the manufactures specifications for the surface aerator up to 20HP. The table show that the 7.5HP or 5.6kw unit is capable of delivering the required aeration level using two unit much like the S&N unit. In the same amount of aeration time as the other units the NSA surface aerator would deliver 660kg-O_2/day. The power consumption would be more than that of the S&N unit because of the more power being used by the motors.

Model	Horse-power		Service Factor[1]		O2/Hour[2]		ØA 1800 rpm input		ØA 1500 rpm input		B		ØC		Weight	
	hp	kw	60hz	50hz	lb	Kg	in	mm	in	mm	in	mm	in	mm	lb	kg
NSA1-08	7.5	5.6	6.50	5.40	26	12	42	1,067	46	1,168	98	2,489	38	965	1,047	475
NSA1-10	10	7.5	4.90	4.06	35	16	46	1,168	49	1,245	98	2,489	38	965	1,112	504
NSA1-15	15	11	3.25	2.70	53	24	49	1,245	52	1,321	98	2,489	38	965	1,203	546
NSA1-20	20	15	2.44	2.03	70	32	52	1,321	57	1,448	98	2,489	38	965	1,253	568

Table 12: The specification of the NSA surface aerators

(Reproduced from DBS Manufacturing, www.dbsmfg.com)

Figure 16: NSA floating aeration platform.

The bridge mounted NSA aerator as its name suggests the aeration unit needs to be mounted onto a bridge structure (Figure 17). The unit operates in exactly the same operating parameters as the floating unit and has the advantages and disadvantages as the floating unit (Table 13).

Model	Horse-power		Service Factor[1]		O2/Hour[2]		ØA 1800 rpm input		ØA 1500 rpm input		B[3]		C		D		Weight	
	hp	kw	60hz	50hz	lb	kg	in	mm	in	mm	in	mm	in	mm	in	mm	lb	kg
NSA1-08B	7.5	5.6	6.50	5.40	26	12	42	1,067	46	1,168	13	330	20	508	1	25	659	299
NSA1-10B	10	7.5	4.90	4.06	35	16	46	1,168	49	1,245	13	330	20	508	1	25	724	328
NSA1-15B	15	11	3.25	2.70	53	24	49	1,245	52	1,321	13	330	20	508	1.25	30	815	370
NSA1-20B	20	15	2.44	2.03	70	32	52	1,321	57	1,448	13	330	20	508	1.25	30	865	392

Table 13: The specification of the Bridge-Mounted NSA aerators.

(Reproduced from DBS Manufacturing, www.dbsmfg.com)

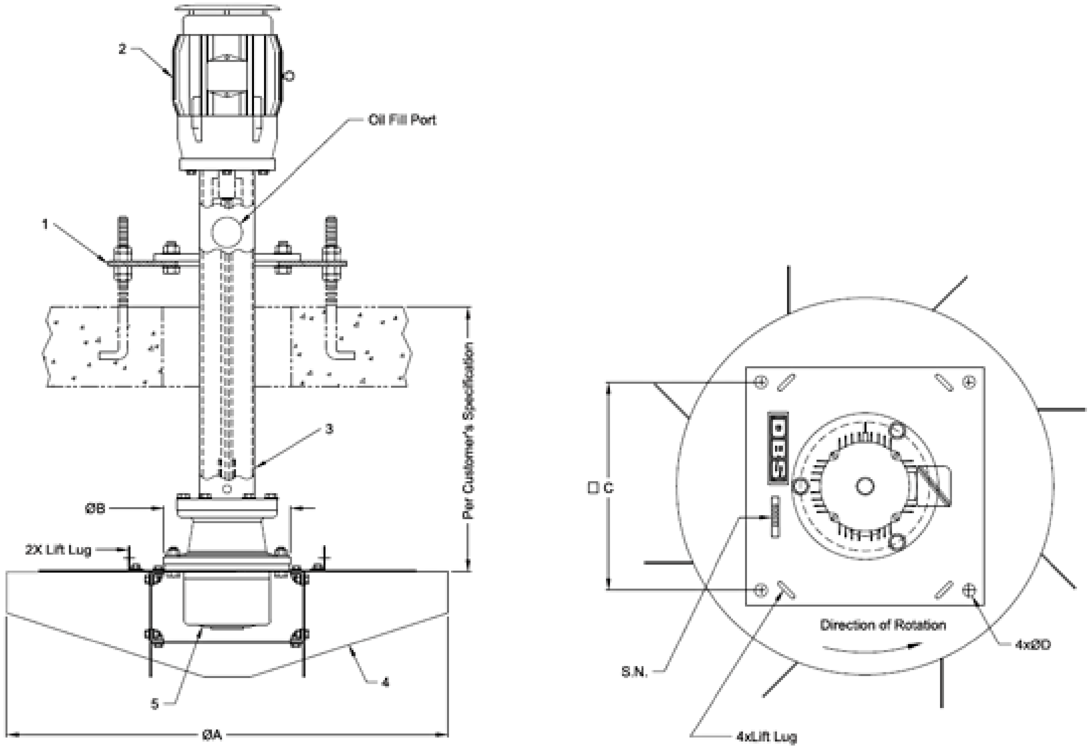

Figure 17: Bridge-Mounted NSA aeration.

The limitation of the two NSA aerators is that they are straight vertical shaft aerators which are not ideally suited to channel aeration process. The units would require the addition of a mixer or blower to create the continuous closed loop circulation to achieve the activated sludge and the settling solids.

All three aeration units are capable of delivering the required amount of estimated oxygen the NWWTP needs for the aerobic treatment process but they all advantages and disadvantages. The S&N Airoflo brush rotor would be the unit best suited to the NWWTP process. The unit can deliver the required amount of oxygen, it can be moved to any location within the ditch, it can be removed from the ditch for ease of maintenance and two units can deliver the same amount or more oxygen and mixing then the current four units deliver.

Larry W. Moore Professor of Environmental Engineering at The University of Memphis in the US carried out testing on the Oxford WWTP as they carried out replacements of their fixed horizontal aerators within the OD. The fixed aerators were replaced with the 15 hp S&N Airoflo floating horizontal brush aerators. As part of the testing the Prof. Moore also change the location of the influent inflow to directly enter the ditch just after there the aerators to enhance the mixing and oxidation. From the introduction of the new aerators and inflow location the site recorded in a short 10 day turn around an increase of DO level of 0.1mg/L to 2.0mg/L. AS part of the test Prof. Moore introduce a anoxic zone by controlling the on-off time of the aerators. While one aerator was ran almost continuously the other aerators where controlled by DO sensors to control the level of DO to create an anoxic region. The sensors where set to start the aerators when the DO level dropped to 0.3mg/L and turn off at 1.0 mg/L of DO. The DO level was kept above 0.3mg/L of DO to inhibit the process from entering the anaerobic process and stopped at 1.0mg/L of do to stop the process from entering into the aerobic process. The expected nitrogen removal of an aerobic treatment process is between 10 to 20 % while an anoxic process can see removals of nitrogen of up to 60%. This type of system and process could be easily adapted to the NWWTP process, not only reducing the power consumption from new aerators but also an increased quality in the effluent. Bur again this can only be achieved with the introduction of monitoring sensors and a controlling system to control the process between aerobic and anoxic, and to avoid the process becoming anaerobic.

Aerator location

Also if new aerators were purchased and in particular the S&N brush rotor aerators where chosen as the replacement aeration units the owners of the NWWTP should consider moving permanent location of the aerators. The aeration system would be able to deliver a high quality treated effluent with improved mix and oxidation if the aerators, in particular the aerator on the inflow side of the channel was located close to the influent inflow pipe. This would is the influent bring mix almost immediately as it enters the channel. It would also have the added benefit of extending the distance from the aerators to the draw off weir which would allow for the effluent to be drawn out of the OD while the aeration process and provide an extended distance for lighter particles to settle.

8.4 Process Control Improvement

The current process control used at the NWWTP would make replacing the current aerators pointless. As stated on many occasions within this report there is no clear evidence that the aerators are the cause of the problems the NWWT. There is not enough monitoring of the processes and the reactions being carried out within the treatment process for any assumption or statements to be made about the aerators. The aerators at the NWWTP are old and compared to the new design aerators they are very inefficient as to the amount of oxygen that is supplied to the treatment process to the amount of power they are consuming. But the issue is still the control of the process and the lack of monitoring and historical data that is available. New aerators could be installed and would more than likely reduce the power consumed but the aeration process. But the question will still be there what is happen within the NWWTP process.

The NWWTP is missing a control and monitoring system. From the research that the author of this report carried out a thousand assumption about what the NWWTP can be made. The limited data and information has left the author question what the treatment process is doing or not doing and why the process is or is not achieving the required treatment levels. At the end this project the recommendations will be still made from assumption based off of the research.

As shown in chapter 7 treatment plants can be improved by adding a control and monitoring system. The NWWTP current system for monitoring the treatment process is very basic. It doesn't or it can't monitor enough of the system or reactions to give any idea of how the process is operate at that point in the treatment cycle. Also the testing is done once a day and in almost all occasion at the same time every morning leaving a 24 hour period where the process could have failed or being head to failure. This whole control and monitoring issue could be rectified for a small initial capital cost. Figure 18 is a combined plot of the recorded DO compared to aerator operating hours for the period between 1/01/2010 to 30/07/2010. The plot makes it impossible to describe how the

NWWTP aeration process is actually running. There are large drops in DO concentration levels even tho the aerators have been operating at a constant average daily hours over a several day period. The opposite is also seen with large increase in the DO concentration levels at lower aerator running times.

The owner could and would gain a better understanding and full control over the system if they were to introduce a dedicated monitoring system that was capable of real time system trending. Once they gained an understanding on what the system is doing they can than direct funding to the develop of a controlling system. At present once a day and only when the operator is onsite testing procedure is allowing the treatment plant to operate outside the treatment process intended operating conditions. The controlling system could include new more efficient aerators or just the addition of VFDs to the current aerators. Sensors and censoring equipment capable of test DO, pH, Temperature and ion-selective sensor are readily available and are very inexpensive and are easy to integrate into a PLC computer monitoring and control system. Computers and data storage devices are also very inexpensive and have become extremely reliable. For an initial outlay of 10 to 15 thousand dollars a computer system could be built with enough redundancy so that the system would never fall over and if it did backups would be available to get the system backup and going within 24hours The system would and could included PLC, software, sensors, communication equipment and backup equipment. Table 14 was made available by SunWaters wastewater division outlay the cost to purchase a monitoring and control system for a treatment plant in far north Queensland. (Table 14 does not included labour to setup system).

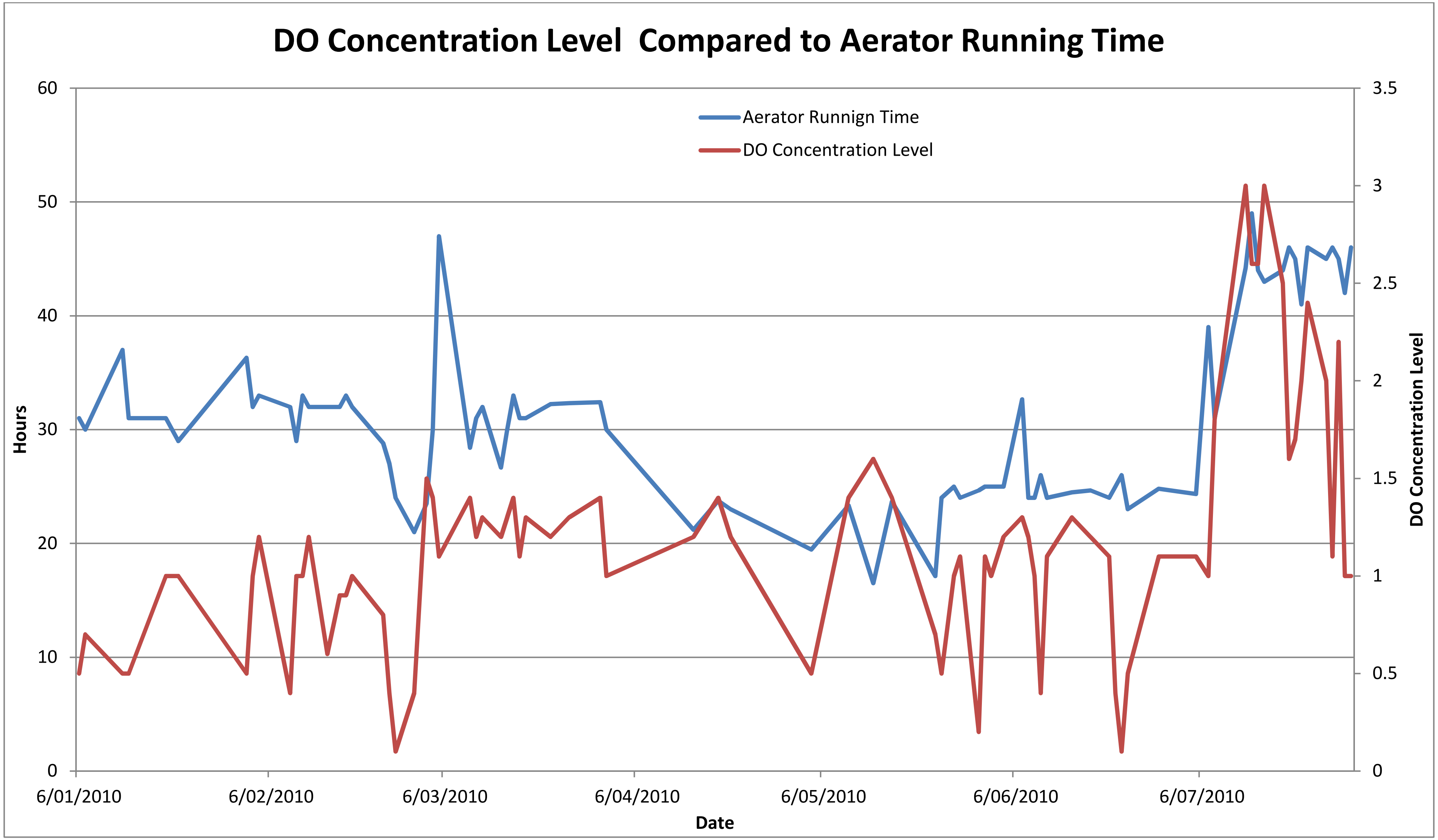

Figure 18: A plot for the DO concentration levels compared to aerator operating hours

Equipment	Description	Estimated Cost
Computer	Dual CPU Server, Dual Power supply, Raid 10 HDD (Cloned and striped)	$3000 to $5000
Onsite NASA	Onsite back HDD system to create a disaster recover backup of the whole system	$1,000
Software	Citech SCADA server edition - A complete software package that is capable and flexibly being designed to monitoring and control any process.	$2,200
	Citech Historian - Stores the data collected from the system that can be recalled and trended into plots and tables	$2,000
	Citech Web console - Allows live monitoring of the designed system onsite and remotely and can be setup to allow operators to adjust the process on the fly onsite or remotely.	$1,500
	Citech Alarm and call out program. Allows the control system to call out alarms via mobile network, fixed land line and radio system.	$1,000
	Windows Server - Basic operating system	$1,000
	Trendmicro Internet Security	$500
PLC	The control input and output control communication devices that are easily intergraded in the Citech system and into any electrical or monitoring device	$2,000
Sensors	DO	$150
	Temperature	$100
	Nitrogen Ion-selective	$320
	pH	$80
UPS	Uninterruptable power supply to allow safe shut down of the computer system. System could be designed to call operator as shutdown sequence begins.	$2,000
Radio	A radio and antenna call out system that requires a licensed frequency	$3,000
ADSL Modem	Standard ADSL modem	$150
Next-G Gateway	Allows internet access over the next-G network	$600

Table 14: The estimated cost to setup a Citech-SACDA system for a remote treatment site operated by Sunwater.

8.5 Alternative OD Setup

The owner of the NWWTP could receive a high quality treated effluent and a reduction in the cost of running the treatment plant if they were to make several small additions and upgrades to the plant. The introduction of DO, pH, Ion-selective, and a temperature sensors, linked into a PLC and computer system would improve the current treatment. But this should be take further with replacing the current aerators with more efficient aerators that could move with the height of the wastewater within the OD. Swapping the location of the new aerators placing one unit closer to the inflow pipe would see immediate mixing and aerating of the influent. Shown in Figure 19 is an alternative layout for a new treatment process at the NWWTP, showing the location of sensors and aerators. The new process could be designed if want or required could have a anoxic zone introduced to improve the nitrogen removal. Linking all this with a water level sensors and a mechanical weir into the SCADA controlled PLC monitoring system. The SBCS would find they would be in control of a modern wastewater treatment facility that has the capability of being operated remotely. A system that would warn the appropriate personnel of break downs or if the process is running outside the control parameters.

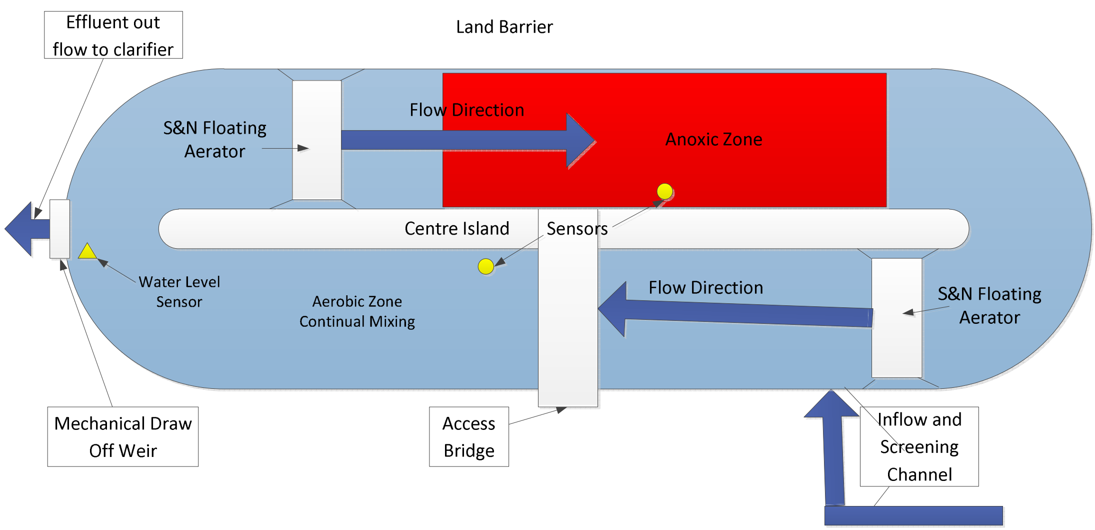

Figure 19 Proposed changes to the NWWTP OD

8.6 Chemical Enhancement

Chemicals are added to the wastewater treatment process to improve the removal of BOD, COD, TSS, phosphorus, heavy metals and any other substance that can be chemically converted to a settable solid (Spellman, 2009). Chemicals can also be added to settling treatment processes to help improve the coagulation and flocculation of organics which are difficult or have difficulty combining into larger particles or with other organic particles. The chemicals can be added to the inflow channel, OD and clarifier, but the chemicals require a good mixing process to avoid unwanted build up within the system.

The main source of wastewater treated at the NWWTP is from the local domestic community, where the town of Nanango has no large industry or commercial business that could be putting trade waste or chemicals through the sewer system. Therefore it would be a mistake to rule out any chemical that are used to treat heavy metals and phosphorus because the process would be using treating domestic waste, where the main concerns would be the BOD, TSS and to a lesser existent COD.

The operators at the NWWTP could carry out a SS test of the clarifier on a regular bases to check the settleability of the SS in the effluent. This would allow the operator to determine if there are SS with the wastewater that are not going to settle no ,matter how length the detention time. From this test they could activate system that automatically doses with chemical or self dose the influent with a chemical to help improve the flocculation and formation of particles. Because there are thousands of particles within the wastewater ranging in size, from as small as 0.01µm they will suspended within the water at different levels passing through the OD and clarifier. The operators at the NTP could test for the SS by taking regular effluent samples from the clarifier discharge. From the sample results and depending on the constitute of the particles, activated silica and sodium silicate could be added to the oxidation ditch to remove the lighter SS. The chemical should be add to the wastewater as close as possible to the aerators in order to gain the best possible mix the of the chemicals with the effluent.

Chapter 9 Recommendation

It is the recommendation of the author of this report that the owner and operator of the NWWTP spend time and resources on studying the treatment plant. The whole treatment process and site should be included in the investigation in particular the secondary treatment process. They should also look to include in the investigation the equipment and operational condition as to age and suited proposes for the treatment process. Also the method of treatment as to whether it is still adequate for the level of treatment the site is aiming to achieve or does the aerobic process need to be modified to introduce an anoxic treatment process.

A review of the operating procedures in particular are they being followed and if so are they out of date and do they need updating. The process control should be looked at as to whether the current methods used to control the treatment systems need to be changing or modified to cope with the changing operational conditions and the age of the plant. Also a major review on how they monitor the treatment plant as a whole and the methods and standards of recording and archiving data and information. It is through historical accurate data that performance, maintenance, and expenditure trends can be developed, which will allow for a better system of planned maintenance scheduling and allows for a whole of life replacement schedule for replacing equipment when it has past its payback period.

Chapter 10 Conclusion

The research shows that the NWWTP is not operating correctly and needs the owner to spend time and resources to find the reason or reasons why the their process is not operating the way it is originally designed. They should before making any decision or spending any money on replacing equipment or upgrading the current treatment plant and/or process they should spend time on monitoring and testing the system and processes. This should be done so the owner can gain a full understanding of current treatment process so that they can compare the findings and results to the original process data and designed operating conditions. An in internal depth investigation and/or audit needs to be carried out on the plants operational conditions with a focus on the secondary treatment process and as to why they are getting inconsistent and erratic DO levels that are testing below what is required for an aerobic treatment process.

The DO results obtained show that the process is not operating as intended or as designed and it is not meeting the owners own set operating conditions for DO concentration levels as stated in the site operating manual. There could be a number of factor that have contributed to the low DO levels. The lack of daily monitoring and testing would be the major contributing factor to the plants inefficiency and the reason for large power consumption. The aerators and the method they are operated and controlled would be of concern to even to those who have had nothing to do with the treatment plants or aeration process. The excessive maintenance and poor DO concentration level results seen at the NWWTP may be due to the age of the equipment but further investigation would suggest that this maybe a just minor contributing factor to the problems faced or there is something else with in the process cause the issues with the aerators.

If the decision to replacing the aerators at the NWWTP was based on the sites daily recorded sheets or even site power bills then this would be a poor decision. From the information supplied and number of assumption could be made as to why the aeration process is consuming power for little to no oxidation of the wastewater. The owner of the NWWTP has looked at the daily recorded sheets and made the assumption that the aerators due to their age and continual maintenance issues must be the problem and should be replaced. And yes this could fix the issue of the secondary treatment process in the short term but it's not answer the question of what is happening within the NTP process to cause the poor performance. The only way gain a true understanding of the NWWTP process is for the owner put resources time and funding towards a dedicated full site monitoring and control system. They should also allocate funding to hiring a third party consultation company that are experts in wastewater treatment and who are completely independent of the SBRC. This should be done so that an un-biases investigation can be carry out to audit the treatment plant and process, the data recording, testing procedures, and the control and monitoring process.

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Appendices

Appendix A Project Specification

University of South Queensland

Faculty of Engineering and Surveying

ENG 8411/8412 Research Project

Project Specification

For: **Jon Turnbull (W0027170)**

Topic: **Improving the Performance of Nanango Sewage Treatment Plant**

Supervisors: **Dr. Laszlo Erdei**
Andrew Grant, South Burnett Regional Council
Steve Carol, South Burnett Regional Council

Project Aim: Investigate the treatment of communal sewage in an oxidation ditch plant to improve the utilization of electrical energy while maintaining or enhancing treatment efficiency.

Sponsorship: South Burnett Regional Council (Water and Wastewater Management)

Program:

1) Research background information regarding biological wastewater treatment. In particular, the review should consider:
   a) the main characteristics of sewage and the major processes used in its purification,
   b) principles of activated sludge based secondary and tertiary sewage treatment, and
   c) characteristics of the oxidation ditch technology, and its development over the decades.

2) Research and analyze historical operational data for the Nanango treatment plant with focus on key information such as:
   a) ditch size, aerators, system monitoring, and relevant physical processes,
   b) historical operational data, including rate of flow of influent, water quality parameters, power consumption of the system, and oxygen delivered by the aerators, and
   c) relevant Australian and state standards, and plant discharge license.

3) Based on the above data, assess the performance of Nanango WWTP.

4) Analyze and determine realistic options to improve plant performance, including
   a) means to improve current plant performance by process modifications and/or enhanced aeration, and
   b) potential of added chemicals and/or carrier media to reduce energy costs and accelerate the treatment processes.
5) Compare prospective alternatives, and make recommendations on the most feasible and economic means to achieve the aims.

6) Submit the required academic dissertation on the work and make an oral presentation.

Appendix B Daily Report Sheet

Nanango Shire Council
SEWERAGE TREATMENT PLANT – DAILY REPORT

Day Thursday Date 8-10-09

	Raw Sewage	Aeration Tank	Clarifier Effluent	Return Sludge	Final Effluent	Imhoff Tank
Diss Oxygen mgl	1.2	.8	.5	-	.4	-
Temperature C	18	17.1	18.8	-	19.2	-
ph	8.29	7.96	7.94	-	7.90	
Time	am	am	am	-	am	am
Chlorine	-	-	Setting -	-	free - total - .8	
Sludge Volume	-		-		-	
SVI	-		-		-	
Sett.Matter						
Clarity	-	-	900 mm	-	-	
NFR.mgl	-		-			

	Time	Ditch New Plant	Imhoff Tank	RAS	WAS
Flow Reading	7:20 am	485750		-	-
Total Flow kl		2106		-	-

	No 1 Aerator	No 2 Aerator	No 3 Aerator	No 4 Aerator	Total Hours
Running Hrs	71	66	68	0	205
Immersion mm					-

Hour Meter Readings (1) 86177 (2) 93148 (3) 97868 (4) 120

Power Consumption

Date	Reading	Consumption 24 Hours
838868 kwh	121740 kwh	854217 kwh

Total Power Consumed kwhs

~~1922 kwh~~	581 kwh	741 kwh	600 kwh
	1	2	3

Weather: Rainfall — mm

Settleability Test

		6 mins	12 mins	18 mins	24 mins	30 mins
1	Mixed liquor	980 mls	970 mls	960 mls	940 mls	920 mls
2	RAS	1000 mls	996 mls	990 mls	980 mls	970 mls

Remarks

NFR

Appendix C Site Operational Manual

OPERATIONS MANUAL

FOR

NANANGO WASTEWATER TREATMENT PLANT

JUNE, 1983

INDEX

1.0 INTRODUCTION

The purpose of this manual is to provide the operator with sufficient background and technical information to be familiar with the operations of the works and to assist when possible by suggestions towards cleaning and maintaining the works to obtain the optimum performance of the facilities.

2.0 DESCRIPTION AND OPERATION

2.1 Introduction

Nanango Wastewater Treatment Plant consists of the old Imhoff tank and the new oxidation ditch plant. The capacity of the Imhoff tank is 1000 persons and the capacity of the oxidation ditch plant is 2500 persons, giving a total of 3500 persons. The oxidation ditch plant is capable of augmentation by an additional plant of 2500 persons.

This Operations Manual will only cover the oxidation ditch plant.

The oxidation ditch process has a low total construction and operating cost. Operation is simple and reliable and is not susceptible to shock loads. Odour problems do not occur and the design produces high quality effluent. The plant does not require units for grit removal or raw sludge handling. The oxidation ditch plant has been designed to produce an effluent quality of 20 mg/L BOD and 30 mg/L non-filtrable residue with chlorination.

2.2 Oxidation Ditch Process

In a conventional activated sludge process, aerobic organisms perform the breakdown of sewage, removing most of the soluble and suspended matter. The solids concentration is in the range of 1000 - 2000 mg/L with a ratio of incoming food to the micro-organisms present (F/M) of 0.3.

The oxygenated environment and a predetermined period of contact between the sewage and the organisms enables the biological oxidation process to be carried out.

The oxidation ditch process utilizes the extended aeration variation of the activated sludge process. The extended aeration variation provides more micro-organisms for the same amount of available food, and a longer period of contact between the two, resulting in more complete removal of soluble and suspended matter.

Carbonaceous matter present in sewage is responsible for most of the BOD. The vast numbers of micro-organisms break down the carbonaceous matter into stable mineral compounds, thus reducing the BOD. Micro-organisms in the channel are comparatively starved, enabling a high consumption of the available food and a low excess sludge production.

Reduction of the bacteria takes place by organisms such as protozoa. Small, inert particles in the ditch are surrounded by bacteria and larger micro-organisms which enable the formation of floc, which is usually expressed as the mixed liquor suspended solids (MLSS).

The MLSS in the oxidation ditch process is in the range of 4000 - 6000 mg/L, compared to the conventional process of 1000 - 2000 mg/L. The food micro-organism (F/M) ratio is typically 0.04, compared to the conventional process F/M of 0.3.

3.0 OPERATION OF THE PLANT

3.1 Introduction

Raw sewage flows by gravity sewer to the treatment plant. Sewage is also pumped directly from Pump Station No. 5. The flow is split between the Imhoff tank and the oxidation ditch in the distribution chamber MH A. The raw sewage entering the oxidation ditch plant is screened and metered in the inlet structure before being mixed with the return sludge and entering the oxidation ditch where it is mixed and aerated to allow treatment to take place. Operation of the ditch is on a continuous basis, with the mixed liquor passing to the clarifier where the activated sludge settles. The supernatant or clarified effluent passes over the weir to the chlorination tank.

The effluent is dosed with chlorine in the mixing chamber and is then detained in the chlorination contact tank to allow disinfection to occur before being pumped to Sandy Creek.

The settled sludge in the clarifier is removed by the sludge scraping equipment and flows to the sludge pump station, from where it is pumped back to the inlet to the oxidation ditch. Waste sludge is bled off to the sludge Lagoons where it is further stabilized and dewatered.

3.2 Screening Channel

The screening channel contains the screening and flow metering facilities.

Screening consists of a mechanically raked screen, a manually raked bypass screen, and an overflow bypass channel. The mechanically raked screen is of the rotary arm type, manufactured by Water Treatment Pty. Ltd. The raking mechanism is activated by either a differential level control device or a time clock. The level control unit is adjustable with a range of 50 - 100 mm and is located adjacent to the screening channel. The timer is located in the switchboard.

Screenings are raked from the screen and deposited into a stainless steel trough. They are washed to the screenings collection basket by a solenoid controlled waterjet.

The flow measuring facilities consist of a fibreglass lined venturi flume, flow detector, integrator and recorder. The equipment is manufactured by Fischer and Porter Pty. Ltd.

3.3 Oxidation Ditch

The oxidation ditch is designed to allow the body of mixed liquor to be circulated continuously. This enables good mixing of the incoming raw sewage and return activated sludge with the mixed liquor in the tank, providing the best possible contact between the micro-organisms and the food.

The ditch is trapezoidal in cross-section with 45 degree sloping walls. Two sets of horizontal rotors, each set consisting of two 2 metre long rotors, aerate, mix and circulate the mixed liquor in the ditch. Three rotors act as the duty rotors, with the fourth rotor being a standby.

The rotors are TNO cage rotors manufactured by Water Treatment Pty. Ltd. under licence from Whitehead and Poole Ltd. (England). The rotors are driven by Crompton - Parkinson motors (one per rotor), operating through a reduction gear, giving a rotor speed of 72 r.p.m.. At maximum immersion of 200 mm the rotors have an oxygenation capacity of 7.5 kg O_2/hour per rotor.

The rotors operate intermittently and are controlled by time clocks located in the switchboard.

The ditch is fitted with a manually adjustable weir to adjust the immersion of the rotors to match the required oxygen transfer rate. The dissolved oxygen in the ditch should be maintained between 1 and 2 mg/L.

3.4 Clarifier

The function of the clarifier is to settle the activated sludge from the mixed liquor. Mixed liquor enters the clarifier through the inlet pipe located in the centre of the tank. The flow is radial from the centre and is deflected downwards by the distribution box. Settled sludge is removed continuously by the sludge scraping mechanism, while the supernantant passes over the V-notch weir to the chlorination tank.

The sludge scraping mechanism is manufactured by Epco Australia, and is of the suction lift type. Sludge is concentrated on the floor by three V-shaped concentrators, and then travels up vertical pipes to the trough located under the bridge. Scum is also removed from the surface of the clarifier into the trough. The sludge flows to the centre column where it is discharged into the sludge outlet pipe to the sludge pump station.

The rate of flow of sludge is controlled by adjustable penstocks located at the outlet of each vertical tube into the trough bridge.

The bridge is supported at the centre column with the drive unit consisting of motor, sprockets, chain and nylon drive wheels, located on the periphery of the tank. The speed of rotation is 25 mm/sec.

3.5 Chlorination Tank

The chlorination tank consists of a mixing chamber where the chlorine solution is added and a chlorination contact tank where the chlorine dosed effluent is detained to allow disinfection to occur. The effluent flows through a 90 degree V-notch weir, and the turbulence after the V-notch thoroughly mixes the chlorine solution with the effluent.

The chlorinator is a Fischer and Porter vacuum operated, solution feed sonic flow device, which includes a vacuum regulator, flow meter, auto flow proportioning control valve and ejector.

The effluent flowrate through the 90^{0} V-notch is measured and transmitted to the chlorinator by an ultrasonic flow transmitter mounted above the V-notch. This signal activates the flow proportioning control valve which adjusts the chlorine gas flow rate to match the effluent flow into the chlorination tank. The control valve will automatically cut out when low or zero flow conditions occur. The water supply required to operate the ejector is 0.63 L/s at a pressure of 250 KPa. The water supply is treated effluent, pumped from the chlorination tank.

The chlorination equipment includes an automatic change over system which consists of a motorized 3-way valve activated by a pressure switch assembly.

The chlorinator and gas cylinders are housed in the control building. An exhaust fan is installed in the chlorinator room and is switched on automatically when the door is opened.

3.6 Sludge Pump Station

The sludge pump station receives activated sludge from the clarifier and pumps it to either the screening channel for mixing with the raw sewage and discharge to the oxidation ditch, or to the sludge lagoons. The flow is proportioned by a 3-way plug valve located in the discharge pipework.

The sludge pumps are Forrers Type TLC submersible sewage pumps mounted on guide-rails. The pumps are automatically controlled by float switches suspended in the pump station. One pump is the duty pump with the other as standby.

3.7 Sludge Lagoons

The sludge lagoons receive waste sludge for further stabilisation and dewatering. Two lagoons are provided, one as the duty, the other as standby. When the duty lagoon is full, waste sludge is fed to the standby lagoon. Supernatant from the duty lagoon is discharged to the oxidation ditch and the settled sludge removed for disposal to land.

3.8 Effluent Pump Station

The effluent pump station receives chlorinated effluent from the chlorination tank and pumps it to Sandy Creek.

The pumps are Forrers Type TLC sewage pumps mounted on guide-rails. The pumps are automatically controlled by float switches suspended in the pump station. One pump is the duty pump with the other as a standby.

4.0 RUNNING OF THE PLANT

4.1 Routine Cleaning and Inspection

The oxidation ditch plant has been designed for fully automatic operation and should require minimal attention as it is inherently stable once operating. Work required to be done on a daily basis involves cleaning various items of plant and checking for correct operation of the system.

Listed below in the form of a check-list are items that need attention on a daily basis.

1. Check switchboard for -

   (a) Fault lights
   (b) Voltage meters and ammeters
   (c) All units operating as required
   (d) Hour meters
   (e) Flow charts

2. Remove screenings from screenings basket. Check that mechanical screen operates correctly.

3. Check operation of rotors. Visual inspection of mixed liquor and return sludge, and check for any floating scum and foaming.

4. Check operation of clarifier scraper for sludge flow through each suction lift tube and for discharge of sludge and scum from the tank through the trough under the walkway of the bridge. Check the clarity of the supernatant and the depth to the top of the sludge blanket. Check the clarifier for floating sludge and any solids carryover across the weir into the effluent channel.

5. Check chlorination equipment for correct operation and note whether changeover of the cylinders has occurred. If it has then the empty cylinder should be replaced. Check the chlorination tank for clarity of the effluent and for settled sludge.

6. Check the operation of the sludge pumps. Note any accumulations of surface scum and settling of solids. Check the discharge of sludge into the sludge lagoons.

4.2 Periodic Cleaning, Inspection and Maintenance

This section describes work which is required on a periodic basis to ensure the plant operates at optimum efficiency. A series of simple tests are proposed to control the operation of the plant. These tests should be performed on a daily basis.

1. Dissolved oxygen levels in the oxidation ditch. This should be maintained between 1 and 2 mg/L.
2. 30 minute settled sludge volume.
3. Effluent stability - methylene blue stability test.

Additional tests are desirable and the degree of control over the plant will depend on the frequency with which the tests are done.

1. BOD_5 - performance testing by comparing raw sewage to final effluent.
2. Mixed Liquor Suspended solids in the ditch (MLSS). This establishes the sludge wastage requirements.
3. Sludge volume index (S.V.I.). This index is a measure of the settling characteristics of the activated sludge.
4. Microscopic examination of the activated sludge.

It is recommended that an operational log be kept to record the operation of the plant. A sample of a monthly log sheet is included (see over). The flow charts which record raw sewage inflows to the plant should be kept.

APPENDIX 'A'

DESIGN OF BASIC UNITS AND EQUIPMENT

WATER TREATMENT PTY. LTD.

NANANGO SEWERAGE

TREATMENT PLANT

CONTRACT NO. S174

HORIZONTAL SHAFT DRIVEN ROTATING AERATORS

OPERATION AND MAINTENANCE INSTRUCTIONS

WATER TREATMENT PTY LTD

I N D E X

WATER TREATMENT PTY. LTD

NANANGO SEWERAGE TREATMENT PLANT — CONTRACT NO. S174

SECTION I : PLANT DATA

TWO SURFACE AERATORS	
NUMBER OFF	FOUR
ROTOR LENGTH	8 METRES
GEARBOX	
NUMBER OFF	FOUR
MANUFACTURER	RENOLD AUSTRALIA
MODEL	WO 5
REDUCTION	20.1
MOTORS	
NUMBER OFF	FOUR
MANUFACTURER	TOSHIBA
FRAME	D132S
KW	5.5
RPM	1440
FULL LOAD CURRENT	11.1 AMPS
BEARING DRIVE END	COOPER 01-B300-CR
NON DRIVE END	COOPER 01-B300-EX
MOTOR DRIVE COUPLINGS	DAVID BROWN MC038
AERATOR DRIVE COUPLINGS	DAVID BROWN MC070
DRAW OFF WEIR	2M LONG HAND OPERATE

WATER TREATMENT PTY. LTD

NANANGO SEWERAGE TREATMENT PLANT CONTRACT NO.S174

SECTION 11 : ROUTINE MAINTENANCE & LUBRICANTS

ROTORS

RENOLD GEAR BOX	SHELL OMALA 320
COOPER BEARINGS	SHELL AVANA GREASE GRADE R2

MAINTENANCE

COOPER BEARINGS GREASE DAILY FOR THE FIRST FOUR WEEKS, THEN WEEKLY.

GEARBOX AFTER 500 HOURS OR ONE MONTH OPERATION, DRAIN OUT, AND FLUSH THROUGH AND RE FILL.

REPEAT THIS PROCEDURE AFTER 2,500 HOURS OR THREE MONTHS THEREAFTER DRAIN AND REFILL EVERY 5000 HOURS.

WEEKLY CHECKS

ROTOR IMMERSION

DRIVE COUPLINGS

OIL LEVEL IN GEAR BOX

Appendix D NWWTP Recorded Aeration Results

	Aerator Run Hours							Dissolved Oxygen			
Date	Aerator 1	Aerator 2	Aerator 3	Aerator 4	Average Total Hrs	Total Daily flow rate (KL)	Average Total Daily flow rate (KL)	Raw Sewage	Aeration Tank	Clarifier Effluent	Final Effluent
6/01/2010	74	0	74	72	220	2848		2	0.5	0.5	2.3
7/01/2010	10	0	10	10	30	374		1.8	0.7	0.7	2.1
13/01/2010	62	0	62	61	37	1748	350	1.6	0.5	1	2.3
14/01/2010	10	0	11	10	31	271		1.4	0.5	0.8	2.2
20/01/2010	63	0	62	61	31	1624	271	0.3	1	0.3	1.6
22/01/2010	8	0	11	10	29	162		0.4	1	0.3	1.4
	227	0	230	224	681	7027					
2/02/2010	128	109	125	1	36	3520	352	0.7	0.5	0.3	1.8
3/02/2010	12	10	10	0	32	382		0.4	1	0.4	1.1
4/02/2010	12	10	11	0	33	368		0.8	1.2	0.2	1.4
9/02/2010	59	49	52	0	32	1871	374	0.6	0.4	0.2	1.5
10/02/2010	9	10	10	0	29	349		0.8	1	0.3	1.5
11/02/2010	12	10	11	0	33	331		0.3	1	0.2	1.6
12/02/2010	12	10	10	0	32	297		0.5	1.2	0.7	2
15/02/2010	36	29	31	0	32	880	293	0.7	0.6	0.2	1.1
17/02/2010	23	20	21	0	32	969	485	1	0.9	0.4	1.3
18/02/2010	12	10	11	0	33	413		0.3	0.9	0.2	1.5
19/02/2010	12	10	10	0	32	355		0.5	1	0.2	1.6
24/02/2010	43	49	52	0	29	1685	337	0.3	0.8	0.2	1.6
25/02/2010	0	14	13	0	27	347		0.4	0.4	0.3	1

26/02/2010	0	2	22	0	24	324		0.1	0.1	0.5	1.1
	370	342	389	1	1102	12091					
1/03/2010	0	36	6	0	21	1037	519	1	0.4	0.4	0.9
3/03/2010	0	47	0	0	24	2923	1462	1.6	1.5	1.1	1.3
4/03/2010	0	24	6		30	628		1	1.4	0.7	1.2
5/03/2010	0	23	24	0	47			0.8	1.1	0.7	1
10/03/2010	0	121	21	0	28	7660	1277	0.2	1.4	1	1.3
11/03/2010	0	24	7		31	467		0.2	1.2	1	1.4
12/03/2010	0	24	8		32	438		0.2	1.3	0.8	1.3
15/03/2010	0	72	8	0	27	1120	373	0.2	1.2	0.3	1.1
16/03/2010	0	23	7	0	30	351		0.4	1.3	0.5	1.2
17/03/2010	0	25	8	0	33	351		0.4	1.4	0.8	1.2
18/03/2010	0	24	7	0	31	325		0.4	1.1	0.5	1.3
19/03/2010	0	23	8	0	31	319		0.5	1.3	0.7	1.2
23/03/2010	0	97	32		32	1121	280	0.4	1.2	0.7	1.3
26/03/2010	0	72	25	0	32	942		0.5	1.3	0.7	1.7
31/03/2010	0	121	41	0	32	1404	281	0.5	1.4	1	2
	0	756	208	0	964	19086					
1/04/2010	0	23	7	0	30	577		1.9	1	0.7	1.3
15/04/2010	0	202	116	0	21	4237	282	1.6	1.2	0.5	1.9
19/04/2010	0	54	41	0	24	1060	265	1	1.4	0.7	1.5
21/04/2010	0	26	20	0	23	568	284	0.2	1.2	0.8	1.2
4/05/2010	0	168	124	0	19	3586	239	0.3	0.5	0.4	1.3
	0	473	516		989	10028					
10/05/2010	0	76	64	0	23	1670	278	1.1	1.4	0.5	1.3
14/05/2010	0	36	30	0	17	1201	300	1.1	1.6	1.3	1.5

17/05/2010	0	39	32	0	24	851	284	1.2	1.4	1.5	2
24/05/2010	0	39	81	0	17	2915	416	1	0.7	0.6	1.4
25/05/2010	0	13	11	0	24	366		1.6	0.5	0.4	1.5
27/05/2010	0	26	24	0	25	686	343	1.5	1	0.4	1.3
28/05/2010	0	13	11	0	24	320		1.5	1.1	0.3	1.2
31/05/2010	0	38	36	0	25	956	319	1.2	0.2	0.1	1.4
	0	280	289	0	569	8965					
1/06/2010	0	13	12	0	25	325		1.6	1.1	0.8	1.5
2/06/2010	0	13	12		25	314		1.6	1	0.7	1.7
4/06/2010	0	13	12	0	25	292		1.6	1.2	1	1.9
7/06/2010	0	51	47	0	33	1132	377	1.9	1.3	1	1.5
8/06/2010	0	12	12	0	24	336		2	1.2	0.5	1.5
9/06/2010	0	13	11	0	24	314		1.9	1	0.8	1.6
10/06/2010	0	13	13	0	26	329		0.2	0.4	1.3	1.6
11/06/2010	0	13	11	0	24	316		1.4	1.1	1	1.6
15/06/2010	0	51	47	0	25	1267	317	1.6	1.3	0.8	1.8
18/06/2010	0	38	36	0	25	934	311	1.2	1.2	1	1.6
21/06/2010	0	38	34	0	24	941	314	1.6	1.1	0.7	1.5
22/06/2010	0	13	12	0	25	320		1	0.4	0.5	1.5
23/06/2010	0	13	13	0	26	319		0.5	0.1	0.8	1.8
24/06/2010	0	12	11	0	23	322		1.5	0.5	1.1	1.6
29/06/2010	0	65	59	0	25	1587	317	2	1.1	0.5	1.7
	0	371	342	0	713	9048					
5/07/2010	0	76	70	0	24	1913	319	1.8	1.1	0.7	1.9
7/07/2010	0	26	13	0	39	523		0.5	1	0.8	1.8
8/07/2010	0	13	9	9	31	271		0.7	1.8	1.5	2.3

13/07/2010	57	58	55	51	44	1498	300	1.1	3	2	2
14/07/2010	12	13	12	12	49	328		0.4	2.6	1.9	2.2
15/07/2010	11	12	11	10	44	311		1.2	2.6	2.2	2.6
16/07/2010	12	11	11	9	43	310		1.4	3	1.6	2.1
19/07/2010	34	35	32	31	44	894	298	1.8	2.5	1.3	1.6
20/07/2010	12	12	12	10	46	337		1.4	1.6	0.6	1.8
21/07/2010	11	12	11	11	45	325		1.2	1.7	0.7	1.7
22/07/2010	10	11	10	10	41	301		1.3	2	101	1.9
23/07/2010	12	12	12	10	46	296		1.4	2.4	1.2	1.9
26/07/2010	35	36	33	31	45	918	306	1.2	2	0.7	1.5
27/07/2010	12	12	11	11	46	321		1.1	1.1	1.6	2.3
28/07/2010	11	12	12	10	45	380		3.4	2.2	0.6	2.3
29/07/2010	11	11	10	10	42	340		1.6	1	0.4	1.7
30/07/2010	12	12	12	10	46	309		1.8	1	0.6	2
	252	374	336	235	1197	9575					
7/08/2009					0						
11/08/2009	41	38	39	10	32	1165	291				
12/08/2009	10	9	9	0	28	275					
13/08/2009	10	9	10	0	29	309					
14/08/2009	10	10	10	0	30	303					
20/08/2009	61	57	58	0	29	1741	290				
21/08/2009	10	10	10	0	30	277					
	142	133	136	10	421	4070					
1/09/2009	112	105	108	0	30	3309	301				
2/09/2009	10	9	9	0	28	307					
3/09/2009	10	10	10	0	30	349					

4/09/2009	11	10	6	0	27	329					
7/09/2009	30	28	33	0	30	979	326				
8/09/2009	11	12	12	0	35	452					
11/09/2009	31	28	29	0	29	898	299	2.8	2.2	1.7	3
15/09/2009	39	37	38	0	29	1106	277	0.8	0.2	0.4	0.3
21/09/2009	61	57	59	0	30	1650	275	1.1	1.6	0.2	0.1
24/09/2009	31	29	29	0	30	825	275	3.3	3	0.5	0.1
25/09/2009	10	10	10		30	281		3	2.7	0.8	0.6
	356	335	343	0	1034	10485					
1/10/2009	62	59	60	0	30	1699	283	1.8	1.6	1	2.8
8/10/2009	71	66	68	0	29	2106	301	1.2	0.8	0.5	0.4
13/10/2009	57	21	49	0	25	1640	328	1.2	1	0.8	0.8
14/10/2009	10	0	9	0	19	98		1	0.8	0.6	1.2
15/10/2009	11	0	13	0	24	389		1.2	1.1	1	1.4
16/10/2009	9	0	9	0	18	227		1	1	0.5	1
20/10/2009	41	0	44	8	23	1188	297	1	0.8	0.7	0.9
21/10/2009	10	0	10	10	30	300		0.8	1.1	0.4	0.4
22/10/2009	10	0	10	10	30	298		1.2	1.8	0.5	2.1
27/10/2009	51	0	49	51	30	1747	349	1.2	1.6	0.8	2.2
29/10/2009	21	0	20	20	31	709	355	1.2	1.4	0.7	2.4
31/10/2009	10	0	9	10	29	334		1.2	1.4	0.8	2.2
	363	146	350	109	968	10735					
4/11/2009	51	0	50	50	38	1565	391	0.8	1.1	0.5	1.7
10/11/2009	91	0	58	61	35	2065	344	0.3	0.8	0.1	1.6
20/11/2009	103	0	99	101	30	3363	336	0.5	1.2	0.5	1.6
	245	0	207	212	664	6993					

1/12/2010	12	12	13	12	49	336		0.3	0.1	0.2	1.3
2/12/2010	13	11	12	12	48	424		0.4	0.7	0.4	1.5
3/12/2010	12	12	13	12	49	336		0.3	0.2	0.2	1.5
6/12/2010	35	35	36	36	47	1127	376	0.8	1	0.8	1.3
7/12/2010	11	11	12	12	46	337		0.4	0.1	0.2	1.3
8/12/2010	11	12	12	12	47	328		0.5	0.1	0.2	1.3
9/12/2010	12	11	12	11	46	330		0.7	0.3	0.3	1.3
10/12/2010	13	13	15	14	55	376		0.2	0.2	0.2	1.4
13/12/2010	34	33	34	34	45	1569	523	0.8	0.3	0.4	1.2
14/12/2010	11	12	12	12	47	408		0.9	0.2	0.8	1.3
15/12/2010	12	11	13	12	48	350		0.4	0.2	0.3	1.3
16/12/2010	12	10	9	12	43	341		0.4	0.2	0.3	1.4
17/12/2010	11	12	0	14	37	523		1.4	0.4	0.4	4.3
20/12/2010	126	92	35	130	128	3924	1308	1.9	1.4	0.5	1.4
21/12/2010	13	15	15	15	58	1656		0.9	1.8	1.6	1.6
22/12/2010	12	13	12	13	50	737		1	1.8	1.2	1.4
23/12/2010	11	14	12	13	50	847		1.2	1.5	1	1.5
	361	329	267	376	1333	13949					

Table 15: Reproduction of the data supplied by the South Burnett Regional Council from the daily report sheets

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